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PAPERS PRESENTED AT THE EIGHTH CONFERENCE ON COAL UTILIZATION

HELD AT THE

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SEPTEMBER 27–28, 1948

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FOREWORD

The eighth Conference on Coal Utilization held at the University of Illinois was offered by the College of Engineering through the Department of Mining and Metallurgical Engineering.

The purpose was to present an educational program of technical and practical information pertaining to coal and its efficient utilization for the benefit of those engaged in mining, preparing, marketing and using coal, as well as for those manufacturing and distributing machinery for the preparation and utilization of coal.

CONFERENCE ADMINISTRATION
1948

M. L. Enger, Dean of the College of Engineering

H. L. Walker, Head of the Department of Mining and Metallurgical Engineering

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I. RECENT DEVELOPMENTS IN COAL PRODUCTION AND PREPARATION

J. A. BOTTOMLEY*

Research in the coal industry, though not very active in the past, has in recent years been receiving considerable emphasis. The industry generally has left new developments in production equipment up to the equipment manufacturers. Most research work has centered on preparation and utilization. Stokers, stoves and special stoker coals have been favorite subjects of investigation.

The loading machine has come into its own in the past two decades, and in recent years great strides have been made in the development of auxiliary equipment, which has been necessary to utilize the mechanical loading machine to its greatest extent.

Rail haulage has been greatly improved through welded track and high speed locomotives. Large and efficiently designed cars provide safe and economical transportation of the coal underground. The advent of the belt conveyor as applied to underground transportation of coal has given rail haulage a very able competitor.

With the so-called "trackless" mines using belt conveyors throughout and those using a combination of belt and rail haulage, mobility of underground equipment has become an important factor. As a result we now see a great number of rubber-tire mounted machines. The flexibility thus obtained has permitted changes in mining methods that have been very helpful. Shuttle cars, as the name implies, shuttle between loading machine and belt conveyor or carloading point. The shuttle cars are large self-unloading cars powered either by battery or by trailing cable.

The coal industry is now facing a new development in underground equipment. This is a continuous mining machine which, now in the development stage, will load coal from the working face without the necessity of cutting, drilling or blasting. The near future should see some radical changes in underground practices as new mining methods and new problems arise from such a development.

In general there have been few changes in design of the underground equipment in recent years. True, each piece of equipment has been improved; but the basic design has seldom been altered. Notable changes have been the addition to the cutting machine of the "bug duster," which carries the cuttings from the machine and greatly reduces the amount of dust made, and the improved cutting and drilling bits.

* President, Sahara Coal Company, Harrisburg, Illinois.

The mechanization of the coal mine, coupled with a highly competitive market, has led to the development and use of elaborate preparation plants for the cleaning, sizing and treating of coal.

Coal cleaning is often called coal washing because most present-day methods entail the use of water in the cleaning operation. Except for the oil froth flotation method of cleaning extreme fine coal, all cleaning methods are based on a specific gravity separation. Clean coal has a lower specific gravity than rock, sand, clay and high-ash middling material, so that a separation can be made at a specified gravity and the ash reduced to a desired point.

The most common method of washing bituminous coal is by use of the multicell baum-type jig. It is possible to treat 7″ x 0 coal in a single unit with rather high efficiency. There have been few changes in design of a jig in recent years. Most changes and improvements have come in the auxiliary equipment such as floats, gates and controls of the jig. Most new plants using jigs now incorporate a small rewash jig to reclean middlings. This gives a maximum recovery through washing crushed middlings and also makes possible a higher-ash secondary product if such is wanted and found marketable.

Heavy-media cleaning is becoming a favored method of washing coal. Though not new to the coal industry, it is receiving new attention due to new developments in equipment designed to handle both coarse and fine coal. This process consists of floating the clean coal in a high specific gravity solution which is a suspension of a heavy and finely ground solid in water. A number of materials may be used; one that is giving satisfaction is magnetite, which can be washed from the coal and recovered magnetically.

More new work is being done in the field of fine coal preparation than in any other. Formerly, the extreme fines were wasted by all wet cleaning plants. The necessity of avoiding stream pollution and the desire to salvage every ton of coal has brought the study of the recovery of fine coal into prominence. When recovered and properly prepared for market the fine coal, commonly called slurry, is a highly satisfactory fuel. The big difficulty in dealing with extreme fines is in the dewatering and shipping of the clean product.

The demand for stoker coal, which has more than doubled since 1940, has brought about the extensive use of crushing and rescreening equipment for the purpose of making stoker sizes from the coarse coal. The trend in preparation plants is to design for maximum stoker production. This means crushing to 1½″ or less with the necessary screens and mixing equipment. Stoker coal is no longer just "fine coal or slack" but rather a highly refined, carefully sized and treated fuel which must and does perform with complete satisfaction.

The treatment of coal to allay dust is still limited rather generally to the use of oil. Some other products have been used with varying degrees of success but the high-viscosity oils are still used on most of the coal treated. Most improvement in the treating of coal has been in equipment to handle these oils. More uniform treatment with oils suited to a particular coal has helped solve the treatment problem.

Freezing of coal is still a major problem with most wet cleaning plants. There are a number of heat and centrifugal dryers on the market to help alleviate this most difficult problem. The use of calcium chloride and coarse salt, applied both dry and as a liquid, has become general at wet plants. It is difficult to measure the amount of good done by these anti-freeze methods as weather at the time of loading and while the coal is being shipped plays such an important part.

II. STOKER COAL

IVAN A. GIVEN*

It perhaps would be oversimplification to say at this point that there is and will be an adequate supply of stoker coal, and sit down. I am assuming, of course, that that is a question uppermost in your minds today. So, to keep in the good graces of the management, live up to the encouragement of some of my friends, and perhaps add something to present thinking, I will try to document my opening statement.

Webster's Collegiate Dictionary defines a stoker as "a machine for feeding a fire." It should logically follow that stoker coal is coal which can be handled by a stoker. But there is more to it than that. The coal must burn when it is placed in the fire. So since the fire and machine are inseparable, provided it is results you are after, the problem is a little more complicated than merely finding something that will go through the machine. That something has to burn, and burn efficiently, when it hits the fire.

I am not going to try to give the specifications for the ideal stoker coal. Others more able than I are working on that problem. What I am going to try to do is discuss briefly the source and supply of stoker coal and some of the things that affect it, such as price and quality.

What you see on the screen (slide) is stoker coal in what might be termed the raw. In addition to the fines, the lumps also are potential stoker coal—and thereby, to fall back on a hoary old saying, hangs a tale. We will deal with that tale more extensively a little later.

What next? I now show you a gravity-screen tipple of 1892. Note the provisions for making at least one size in what is now the stoker-coal range: 1½ or 1¼ by ¾ or ⅝.

Here is reportedly one of the first plants to be erected in Saline County, Illinois, for making a multiplicity of sizes. Note particularly the 1¼ x ¾ fraction, among others. Again, this size is in the present stoker-coal range.

From this, as has long been apparent, there is at least one further step before stoker coal can be produced after the coal is shot out of the solid in the mine. That step is simple screening to take out the oversize.

Screening, however, is by no means the last of the steps that many consider necessary for a proper size and quality of stoker coal.

* Editor, *Coal Age*, New York.

Removal of the fine sizes or dust is a general practice. This brings in double screening, which you see here; for the operator it involves at least the following:

1. An extra screening cost.
2. The problem of disposing of the dust and fines. At the moment, this is not too difficult, but it has been a problem in the past and may be again in the future.

Along with size, impurity content is a major factor in consumer, dealer and producer thinking about stoker coal. The only real way of tackling the problem is mechanical cleaning, since there is no other practicable way of achieving maximum refuse elimination and uniformity of product. But mechanical cleaning requires equipment, power and labor, again increasing the cost that properly should be assessed against the final product.

Here (slide) is a mechanical plant that was installed especially for preparing nut and stoker coal, particularly the latter. It is noteworthy because it is a small plant for a small mine. Maximum washer capacity is 60 t per hr, while the present rate of operation is 30 t per hr.

This plant and many others much larger in size, such as this one now shown on the screen, are evidence that the coal industry appreciates the importance of the stoker-coal market, in spite of the extra investment and operating cost involved, including tramp iron removal and treatment to suppress dust. These last two operations also involve expense for equipment, materials, power, operation and maintenance that may or may not be completely returned by any special charge that may be made, as for dustproofing.

So far we have been dealing with stoker coal in quantities naturally made in mining operations. What happens if the natural yield is not sufficient to meet all demands? The coal industry's answer is crushing of larger sizes as necessary. I don't know how many crushers have been installed in coal preparation plants, but up in the thousands. Practically all have been bought to augment the supply of the finer sizes—stoker in particular. You will note three in this flowsheet of a modern mechanical plant. You will note also that this plant includes comprehensive equipment for rescreening, mixing and blending for the production of stoker.

All these crushers in the industry increase the production of the finer sizes at the expense of the coarser. It sounds simple but it presents the mine operator with a problem vitally affecting his prospects for a profitable operation. Let us assume a rather simple situation and see what happens. Before crushing, the size yield and realization for this assumed mine might have been as follows.

	Percentage of Output	Price per Ton	Realization
6-in. lump	10	$6.00	$0.60
6 x 3 egg	20	6.00	1.20
3 x 1½ nut	25	5.00	1.25
1½ x ½ stoker	20	4.00	0.80
1½-in. screenings	25	3.00	0.75
Total	100		$4.60

Now, if it was decided to crush egg or nut or both to increase the stoker output, the picture might change to the following:

	Percentage of Output	Price per Ton	Realization
6-in. lump	10	$6.00	$0.60
6 x 3 egg	15	6.00	0.90
3 x 1½ nut	20	5.00	1.00
1½ x ½ stoker	28	4.00	1.12
1½-in. screenings	27	3.00	0.81
Total	100		$4.43

By crushing to increase stoker-coal output, the operator in this assumed example either has to raise his prices or take a licking of 17 cents per ton on realization. I can assure that in the coal industry 17 cents per ton is important money, even today.

The fact that thousands of crushers are in service is evidence that the coal-producing industry is willing to face up its responsibilities and also take advantage of its opportunities. The price of stoker coal has gone up; it is plain to see that it had to. If the coal producer were at all inclined to be tough about recovering all the costs involved it would be even higher.

Sober consideration also will lead logically to another conclusion: stoker-coal production normally will increase just as fast as demand and no faster. Few producers enjoy raising prices. Neither can they stand a substantial decrease in realization as a result of increased crushing, without price adjustment. It should not be expected, therefore, that the coal industry will increase stoker-coal output merely for the fun of it. There has to be a real reason.

Let me hasten to say that this most emphatically does not mean that the coal producer is hostile to the stoker. On the contrary. The producer welcomed the stoker as a market holder and builder and the industry has spent heavily of its own funds and time in promoting the development and sale of stoker equipment. It is spending even more heavily on equipment for producing better coal, including stoker coal, at the lowest possible prices.

Expenditures for new equipment and plants for cutting cost and raising quality are running better than $200,000,000 annually, according to informed estimates based on surveys of expenditures by a substantial number of companies. In other words, for every ton the industry is producing today, it is spending at least 30 cents for new plants and equipment. That may not sound like an imposing figure but it is as much as, and quite likely more than, the average profit per ton today after taxes.

A major part of the industry's expenditures naturally is going into mining and stripping equipment to reduce cost. In 1947, for example, purchases of loading machines by coal mines were the second highest in history and only nine machines less than the all-time high of 495 in 1946. And in a search for even more efficient equipment, the bituminous industry, through a special committee affiliated with Bituminous Coal Research, Inc., has raised several hundred thousand dollars to work on the development of additional machines of the continuous mining and loading type to supplement those already going into production. These new machines will provide an additional substantial cut in production cost, with attendant favorable effect on the price of coal to the consumer.

On the preparation side, the record also is one of increasing installation of new plants and equipment. It is no secret that the war resulted in a relaxation of preparation standards in some quarters. The last few months, however, have witnessed sharp action to correct this situation by not only producers but consumers. With the rising rate of installation of new preparation equipment, the future undoubtedly will see even greater emphasis on good preparation.

After dropping off during the war for obvious reasons, including a tight steel supply, activity in the installation of new preparation equipment turned upward toward the end and afterward. The record since 1941, according to data compiled annually by *Coal Age*, is as follows:

Bituminous Coal Preparation Projects

	Number of Projects	Hourly Capacity
1941	117	23,071
1942	40	11,475
1943	49	8,121
1944	67	18,896
1945	78	18,840
1946	76	25,565
1947	95	21,592
Total	532	124,560

The totals in 1946 and 1947 undoubtedly would have been substantially higher had it not been for the aforesaid steel shortage as well as a tight construction and design labor supply. Nevertheless, the capacity of the new preparation facilities installed in these seven years is equivalent to an annual output of at least 150,000,000 t and perhaps more than 200,000,000. In other words, at least one-quarter and perhaps one-third of the industry's output is coming from — or when construction is completed will come from — new plants and facilities installed or contracted for in just seven years, not to mention the large additional capacity represented by new facilities installed earlier.

Not all new preparation equipment installed in these seven years was specifically for stoker-coal production. However, analysis of the contracts indicates increasing emphasis on mechanical cleaning, screening and, if wet washing is employed, drying of sizes from 2 in. down — the range from which stoker coal is derived. In addition, the capacity listed immediately above does not include an unknown but substantial total represented by installation of crushers and vibrating screens — the usual facilities installed when stoker production is increased, since these are not specifically canvassed by *Coal Age* and appear only when included in a contract by a regular builder of preparation plants. There also is another modest trend, which will become increasingly important in the future — the design and construction of plants designed for producing stoker coal and nothing else. Several of these are in service or are planned and, as stated, the number undoubtedly will grow.

A growing number of the new stoker-coal plants also are pretty fancy establishments designed to mix, blend and oil-treat to provide practically any desired quality and size consist. In other words, they make stoker coal to practically any specification desired by the customer. An example is the plant shown on the screen. It involves storage bins, variable-speed feeders, a blending belt and oil-treating facilities. By changing the sizes placed in the bins and by adjusting the speed of the feeders, a stoker coal with any desired characteristics as to size makeup can be produced and oil-treated. Not all plants are on the same scale as this; on the other hand, some are even more elaborate. The trend is toward the more elaborate operations providing a better opportunity to adjust the quality characteristics of the product as desired.

Some of these stoker-coal plants also involve fancy investments. H. A. Glover, vice president in charge of sales, Island Creek Coal Sales Co., in a paper on "Domestic Stokers and Stoker Coal" presented at the June 1948 meeting of the Stoker Manufacturers' Association, cited one plant requiring 18 months and $75,000 to obtain the equipment to extract the ⅜ x ⅛-in. fraction from the regular run of product to make a midget stoker.

"This is all very fine," you may say, "but there still is a shortage of stoker coal." Is there? I did considerable figure-chasing in preparing this paper. There are one or two items that I would like to present. One is that a study of government reports on shipments by sizes in 1946 as compared to 1944 shows that even though the 1946 bituminous production was 86,000,000 t less, the shipments of sizes in the stoker-coal range were approximately 3,750,000 t more than they would have been if the 1946 percentage had not increased over that of 1944. Futhermore, retail dealers apparently got more than 3,000,000 out of this 3,750,000 of extra production of coal in the stoker range in 1946. This indicates, I believe, that the retailer and the stoker user are not being disregarded.

With all due respect to the figures, however, I say that there is a plain answer to any arguments that there is a real shortage of stoker coal. That answer grows out of the fact that there are no reports — or at least none that I know of — of stokers having to be shut down or pulled out of homes and plants because there was no coal available — in a few instances perhaps, but certainly not on any significant scale.

What about the future? K. C. Richmond of *Coal Heat*, who knows his way around as well as any man I know, forecasts a demand for coal for small stokers in the neighborhood of 64,000,000 t in 1952, an increase of around 20,000,000 over the consumption in 1947. Can it be met? The answer is "Certainly." It will require a major increase in crushing and undoubtedly further price adjustments, but there is no bar to reaching this goal either in the productive capacity of the industry or in its ability to provide the facilities to prepare it.

The industry is already, in fact, moving to raise its output of stoker coal substantially. In this connection, I take the liberty of referring again to Mr. Glover's paper, which is well worth studying; it can be found in the June-July 1948 issue of *Coal Heat*. Mr. Glover surveyed a cross-section of important shippers of domestic coal in Illinois, the high-volatile districts of eastern Kentucky, West Virginia, Virginia and Tennessee, and the low-volatile districts of West Virginia. Using shipments in the coal year 1946-47 as 100 percent, the survey showed the following:

	Actual Shipments, 1946-47	*Actual Shipments, 1947-48*	*Estimated Shipments, 1948-49*
Residential stoker	100.0%	128.4%	162.6%
Commerical stoker	100.0%	112.8%	128.2%
All other coals shipped for retail distribution	100.0%	109.5%	127.4%
Total, all coals shipped for retail distribution	100.0%	115.4%	137.7%

You will note the substantial increase in shipments of coal suitable for domestic-stoker use, and also that in total coal for retail distribution. It would not be fair, perhaps, to apply this rate of increase to the entire country, but even if it were only half for the country as a whole it would mean that retailers in the coal year 1948-49 would receive at least 15,000,000 t more coal, of which I would estimate up to more than half would be suitable for domestic and commercial stokers.

This is figure-juggling, I admit; events may or may not confirm these speculative conclusions exactly. Basically, however, there is a major increase ahead in the production of stoker coal — not only in the plans for increased output at existing operations but in the boost in productive capacity now under way in the industry. This latter is a factor that has not, I believe, been given due weight in discussion of the stoker-coal supply.

To get some idea of the increased productive capacity to be expected in the future, Keystone Coal Buyer's Manual, a *Coal Age* affiliate, recently addressed a series of questions to all coal producers, anthracite and bituminous. The replies on plans for increasing capacity indicate that by 1950 the bituminous industry will be in position to produce 50,000,000–60,000,000 t a year more than at present, which should materially ease the stoker-coal problem, aside from the plans for increasing stoker-coal output at operations now in existence.

A great deal more might be said about the stoker-coal situation. It would merely confirm, however, the opinion I expressed at the opening of this paper: the supply of stoker coal has been adequate in the past, although tight for obvious reasons in recent years, and will be adequate or plentiful in the future. In other words, if the stokers are sold the coal industry will have good coal for them at a reasonable cost.

III. CHANGING FUEL REQUIREMENTS IN THE ILLINOIS TERRITORY

W. H. Voskuil*

The Illinois Coal Market Area Defined

The territory designated as the Illinois coal market area comprises the states of Illinois, Wisconsin, Minnesota, Iowa, and Missouri, and eastern cities and counties of Kansas, Nebraska, and the Dakotas. The boundaries are determined by competition from other coal fields and other forms of fuel. More than 90 percent of the coal produced in Illinois is marketed in this area. In the southwestern part of the area the market is dominated by fuel oil and natural gas almost to the exclusion of coal. In the Dakotas, Kansas, and Nebraska the westward flow of Illinois coal is met by an eastward flow of coal from Colorado, Wyoming, and Montana. In the lake shore counties of Minnesota and Wisconsin the market is dominated by coal from the Appalachian region because it can be carried cheaply by water to ports along Lake Michigan and Lake Superior. Southern and western sections of both Wisconsin and Minnesota are large consumers of Illinois coal, which moves into these areas by both rail and water on the upper Mississippi. Only small quantities of Illinois coal are shipped eastward, most of which goes to coking industries in northern Indiana. The eastern market is supplied almost exclusively by coal from Indiana and the Appalachian area of Ohio, Pennsylvania, West Virginia, and eastern Kentucky.

In 1945 the total consumption of coal in the Illinois coal market amounted to 80,971,570 t of which 38,059,996, or 47 percent, was furnished by Illinois mines. This was 93 percent of the total 40,841,754 t of 1945 rail shipments of Illinois coal, exclusive of railroad fuel, which accounted for an additional 23,000,000 t.

Competitive Fuels

Even with this tonnage of Illinois coal moving into these states, the Illinois coal market area is by no means dependent on Illinois coal. Besides the shipments of Appalachian coal to Minnesota and Wisconsin, large quantities of Appalachian coal move into Illinois itself, particularly into the domestic and commercial markets of the Chicago area. Local coal from Missouri and Iowa share those markets with Illinois coal. Fuel oil and natural gas are also important competitors throughout the area.

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A summary of the energy consumption in the Illinois coal market area in 1945 (except for fuel oil and gas) gives an idea of the competitive position of fuels in the area:

Coal	*Total Consumption*
Bituminous (tons)	80,971,570
Anthracite (tons)	1,108,260
Coke (tons)	7,106,675
Briquets (tons)	1,961,576
Fuel oil (barrels)	78,234,000 (for 1943)
Natural gas (M cu ft)	419,420,000 (for 1944)
Water power (M kw-hr)	7,740,408

Data on fuel oil and natural gas consumption are not available for 1945.

We use annually in the United States the fuel equivalent of a billion tons of coal, more or less. We derive our fuel and power requirements in the main from four natural sources—coal, petroleum, natural gas, and water power. Oil in shale may some time become a source of fuel, and to this must be added a possible contribution to power requirements by nuclear energy.

Fuels in the raw state as mined or produced from wells have but a limited and restricted usefulness in industry. Varying degrees of fuel preparation are necessary if the tasks of industry are to be accomplished. Fuels are needed in solid, liquid, and gaseous forms in several types of each. To this must also be added electrical power—energy in a nonmaterial form. The types of engines, using this term in a very comprehensive manner, must also consist of many types and forms. Among these, power provision devices are steam engines (and boilers), internal combustion engines, hydraulic engines, blast furnaces, ovens, and retorts.

Our modern industrial economy calls for several specifically prepared fuels which permit of no substitution. The tendency in fuel preparation is an increase in number of specially prepared fuels as a means of increasing the efficiency with which the fuel performs in a given operation.

The function of fuels in industry may be grouped broadly into two general categories, supplying heat and supplying power. Within each there is so wide a range of requirements that a correspondingly wide variety of prepared fuels are needed to accomplish the desired results. In particular, some industrial processes require specially prepared fuels for which substitution is impossible or impracticable, whereas other processes are tolerant in their fuel requirements. This is especially true in the so-called "heat-using" industries. In the

"power-using" industries, a wide variety in size and in function of power units calls for fuels in various specialized forms. Conversely, the availability in the United States of ample quantities of fuels in the solid form, in liquid form, and gaseous fuels at relatively low costs provides an opportunity for development of power-using activities that would be out of the question if the supply of fuel in its natural state were limited to coal alone.

In "heat" operations, there are two general classes of requirements. One is the smelting of ores — a reduction process requiring both heat to raise the ores to a temperature in which the desired reactions take place, and carbon to unite with the oxygen in the ores. In this case a special type of fuel is required. A second general class of heat operations involves mainly production of heat to raise process substances to high temperatures.

In "power-using" industries the motor varies from the huge stationary turbine of the power station, fired by coal and driven by steam, to the small, mobile, internal-combustion engine unit of a lawnmower, or a combination of the steam turbine as a prime mover and power transmitted to distant point through the generator to an electric motor, frequently of fractional horsepower.

In the many applications of heat and power to industry, the selection of fuels in each particular use is governed by two general considerations — technology and relative cost. Technology sets the limit within which one fuel can be substituted for another. Price is the selective process by which one out of several possible fuels is chosen. Out of the several raw-fuel types available we apply varying degrees of preparation, from simple screening operations to a high degree of preparation represented by the process of coking or oil refining and even to the extent of synthesizing fuels from simpler raw materials.

Fuels in Manufacturing

For an analysis of fuels in manufacturing, the data for the year 1939 are selected, partly because a more detailed breakdown is possible from the Census data and partly because the demands upon the fuels by World War II had not affected consumption in 1939 sufficiently to distort a peacetime pattern of fuel and energy consumption.

Of this total of 241,000,000 t used in manufacturing, the immediate consideration is to distinguish quantitatively the special noncompetitive fuels and fuel applications from those manufacturing uses in which competition among the fuels is technologically possible and does in fact exist.

TABLE 1

FUELS USED IN MANUFACTURING IN 1939[a]

Fuel	Quantity	Percent	Quantity, Coal Equivalent, tons
Bituminous coal	....	59.3	137,771,432
Anthracite	....		5,015,857
Coke	....	....	(35,115,357)[b]
Fuel oils, bbl	133,773,524	13.7	33,050,000[c]
Gas, natural, mcf	886,806,520	14.8	35,472,260[d]
Gas, manufactured, mcf	1,283,749,085	....	(65,000,000)[b, e]
Gas, mixed	24,536,718	....	(500,000)[b, e]
Purchased electric power, M kw-hr	45,040,075	12.2	29,276,046[f]
Total, less coke, mfg. gas, and mixed gas		100.0	240,585,595

[a] U. S. Census.
[b] Figures in parentheses not included in the total.
[c] Conversion factor: 170 gal. equals on 1 t of coal.
[d] Conversion factor: 25,000 cu ft of gas equals 1 t of coal.
[e] Conversion factor: The conversion factor for manufactured gas presented some unusual difficulties by reason of the several sources and varying Btu values of this type of gas. In the manufacturing industries in general and the iron and steel industry in particular, gas is obtained both from the by-product coke oven and from the blast furnace. The latter is of a Btu value somewhat less than 100. For the aggregate of manufactured gases, an arbitrary figure of 250 Btu's per cu ft has been assigned.
[f] Conversion factor: 1 kw-hr equals 1.3 lb of coal.

Among the more than 200 manufacturing industries listed by the Census, the largest single user is the iron and steel industry.* Although there are two distinct phases of this industry — the reduction of iron ore to pig iron and the preparation of steel in ingot form and subsequently in semi-finished steel shapes — the fuel consumption figures reported by the Census cover the entire industry, and analysis will be made accordingly.

The blast furnace and steel works consume approximately 30 percent of all fuels used in manufacturing industries (1939 data), as shown in Table 2.

We can attempt to arrive at a total fuel consumption by considering original fuels and by converting coke quantities to the equivalent coal quantities charged into ovens to make the total 32 million tons of coke. If the average coke recovery is 70 percent, the coal requirement is calculated to be 45,874,043 tons. We further assume that the manufactured gases used in steel manufacture are derived from the coal processed in the coke ovens.

* Although the Census lists the oven-coke industry as the largest consumer of fuel, this is a fuel preparation industry, transforming coal into coke accompanied by the separation of gas and tar from the raw coal. These latter products, with coke, are used as fuels in steel and other industries, and are calculated in the fuel consumption of the strictly fuel-using industries.

TABLE 2

FUELS USED IN THE BLAST FURNACES AND STEEL INDUSTRY: 1939*

Fuels	As Reported by the Census	Converted Into Fuel Equivalent	Fuel by Original Source
		(Tons)	(Tons Equivalent)
Anthracite, t	342 945	342,945	342,945
Bituminous coal, t	9,227,872	9,227,872	9,227,872
Coke, t	32,092,930	32,092,930	45,874,043
Fuel oil, bbl	27,387,058	6,846,764	6,846,764
Natural gas, mcf	102,032,341	4,080,000	4,080,000
Manufactured gas	1,025,093,492	....	....
Coke oven gas, mcf	237,820,694	4,957,814	....
Other gases	787,202,898	3,000,000	....
Mixed, mcf	6,431,604	128,600	....
Electricity, kw-hr			
Generated in plant	5,680,082,722	....	....
Purchased	5,116,980,842	....	....
Sold	1,349,587,089	....	....
Net purchased	3,767,393,753	2,448,806	2,448,806
Net used	9,447,476,475	....	....
		59,925,731	68,820,430

* Source: U. S. Census, *Manufacturers*, Vol. 1.

While the fuels used in the manufacture of iron and steel are drawn from all sources of natural fuels and perform, in this complex industry, both heat and power operations, the crucial operation is the reduction of iron ore to the metal. For this operation a fuel is required which supplies heat and also serves as a reducing agent. The distinctive characteristics of the fuel requirement in the iron and steel industry are the exacting requirements of the fuel used in the blast furnace and the interrelationships of the blast furnace fuel and its by-product fuels with the subsequent operations in the steel industry. Although the reducing agent in the furnace is carbon monoxide, the fuel used is carbon in the form of coke. In addition to supplying the basis for the reducing agent, the fuel used in the blast furnace must have also strength to sustain the heavy weight of the furnace burden and porosity to provide a large surface for quick-burning. For this purpose the product of the destructive distillation of coal — the hard, porous, devolatilized coke — is for all practical purposes the only suitable fuel. Other methods of reducing iron ore have been proposed but to date the reduction of iron ore in the blast furnace using coke as a fuel is so superior in terms of economy that there are no rivals. This is of fundamental significance, for it is at present the only means we have for obtaining iron cheaply.

Manufacturing Other Than Iron and Steel

The distinguishing characteristics of the iron and steel industry, in addition to the large and exacting nature of requirements, are the

TABLE 3
FUELS USED IN GENERAL MANUFACTURE*

Fuels	Total	Exclusive of Iron, Steel, and Oven Coke Industries
Anthracite, t	5,015,857	4,672,912
Bituminous coal, t	137,774,432	67,079,920
Coke, t	(35,115,357)	(3,022,427)
Fuel oil, bbl	133,773,524	106,386,466
Natural gas, mcf	886,808,520	784,776,179
Manufactured gas, mcf	(1,283,749,085)	(219,135,102)

* Figures in parentheses in this table are manufactured products of bituminous coal and are not to be added in totals of all fuels used.

large tonnage of raw ore and raw fuel that must be moved and treated before the free metal is obtained. These characteristics not only limit iron production to districts where these several bulk materials — coal for coke making, iron ore, and limestone — can be assembled at a minimum cost, but further restrict the production districts to a close proximity to the type of coal resources from which coke can be made.

Electric power in industry has four major use forms — lighting, 7.80 percent; motors, 62.08 percent; electrolytic cells, 13.97 percent; and electric-furnace use, 13.73 percent. The percentages show the distribution of use in 1945.

During the period 1939–1946 the use of electric power in manufacturing increased somewhat more rapidly than did that of other forms of fuel. The comparative rates of increase are shown in a table not reproduced herein. An analysis of electrical power consumption by industry groups in the period 1939–1946 as given in that table shows that the largest increases were in the chemical group, iron and steel, nonferrous metals, petroleum and coal, transportation equipment, machinery, electrical machinery, and rubber. Since these were dominantly war years, certain increases can be related to this factor. The increase in iron and steel was no doubt enhanced by a rise of electric steel output from an index of 100 in 1939 to 445 in 1943, whereas total steel in this same period advanced from 100 to 169.

One of the outstanding increases in electric power consumption since 1939 has been in the manufacture of aluminum. Electric power consumption rose from an estimated 3.2 billion kw-hr in 1939 to an estimated 18.4 billion in 1943, the peak year of aluminum output. The rate of increase in the nonferrous industries — in total, and exclusive of electric power used in aluminum reduction — is shown in a table not reproduced herein.

The use of electricity in manufacturing may increase somewhat in

the future with the expansion of electric furnace production of fine steels, in the nonferrous metal industry, especially in the use of electrolytic processes. It will probably not effect revolutionary changes in the manufacturing industries nor affect the use of any of the fuels. The use of electricity has had the effect of virtually adding one more source of power, i.e., water power, a form of energy which would probably have a restricted usefulness except as it can be transformed into electric power and so used.

Railroad Fuel

Railroad fuel is an important factor in the coal industry of the United States. The large areas of the nation and the development of geographical localization and specialization of production with the resulting long hauls of raw materials is reflected in the high fuel consumption by railroads. There is a marked contrast in the railroad fuel requirements of European industrial nations and the United States. In 1937, selecting a prewar year of somewhat moderate business activity, Germany used 15.5 million tons of coal for railroad transportation, England used 13.3 million tons and the railroads of the United States used 82.7 million tons of coal and about 16 million tons equivalent of fuel oil.

The war period, 1940–1946, saw an increase in railroad fuel consumption and a somewhat more rapid growth of liquid fuels than coal. Coal declined from 80 percent of all fuels used by Class I railroads in 1940 to 70 percent by these roads in 1946.

The significant development in liquid fuel used by railroads is the rapid growth in the use of diesel fuel. Although the fuel contribution to the total railroad equipment is still comparatively small, the growth since 1940 has been very rapid and, what is more significant, it represents the introduction of the internal combustion engine in railroad transportation, challenging the position of the steam locomotive. The trend toward installing diesel-powered locomotives on railroads gained impetus after 1940; it shows no signs of diminishing.

The questions posed by such a program are: How much diesel fuel will be required to replace the 100,000,000 t of coal used by the railroads at present, and secondly, What will happen to the price of diesel fuel? On the question of coal displacement by diesel fuel, these data are offered by the Interstate Commerce Commission.*

> On the basis of the average rate of coal consumption by coal-burning locomotives in each of the three services (switching, freight, and passenger service) diesel-electric locomotives displaced over 14,136,625 tons of coal in the first eight months of 1946.

* Monthly Comment on Transportation Statistics; Bureau of Transport Economics and Statistics, Interstate Commerce Commission, Nov. 13, 1946, pp. 4-5.

During this same period the actual consumption of diesel fuel in locomotives was 328,416,469 gal., the equivalent of 1 gal. of diesel fuel for 86 lb of coal. On this basis the 2,340,000,000 gal., or 55,000,000 bbl, of diesel fuel would have replaced the 100,620,000 tons of coal used by railroads in 1946. If the reasoning that 328,416,469 gal. of fuel oil displaced 14,136,625 tons of coal is sound, then, using the figures of cost given in this same report — i.e., $3.73 for a ton of railroad coal and 5.49 cents per gal. for diesel fuel, $18,030,064.15 as oil costs did the work of $52,729,611.25 as coal costs, or a ratio of 0.34 to 1.

This comparison must not be considered as conclusive, although the available data apparently point in that direction. Fuel costs are subject to change through changing efficiencies as well as changes in price. In the meantime the trend of locomotive purchases by railroads is in favor of diesel-powered locomotives, indicating that the total over-all cost of railway motive power is apparently in favor of these types of engines.

The Gas-Turbine Locomotive

The coal-fired gas-turbine locomotive is admittedly an attempt to hold the railroad fuel market for coal, which the existing steam locomotive is apparently unable to do. This type of locomotive is still in the developmental stage and is expected to be undergoing on-the-rail tests soon.*

> Gas-turbine locomotives are expected to burn less than 1 lb of coal per rail horsepower-hour without smoke, cinders, fly ash or slag; cost no more to purchase than a diesel and weigh considerably less; need no water except the train-heating boilers; require less maintenance than the steam or diesel locomotive . . . .
>
> Major advantage of the gas turbine will be its ability to burn low-cost coal. Although the thermal efficiency of the diesel is higher, the fuel bill of the gas-turbine locomotive with electric drive will be about one-third that of the diesel, one-third to one-fourth that of the modern steam locomotive and approximately one-eighth to one-tenth that of the older steam locomotive . . . .†

Comparative fuel costs of locomotive operation of the coal-burning gas turbine locomotive and the diesel locomotive is given as 9.8 cents and 30.4 cents respectively. The figures for the coal-burning gas turbine are calculated, as no test locomotive or large turbine has been built.‡

The above claims have yet to be substantiated; in fact the successful operation of this type of locomotive is yet to be established.

* Stanbury, W. A., Jr., Gas-Turbine Locomotive, *Coal Age*, October 1946.
† Stanbury, W. A., Jr., Gas-Turbine Locomotive, *Coal Age*, October 1946.
‡ Petroleum News, August 7, 1946, p. R563. The article does not state the price of the coal and diesel fuel on which this estimate of comparative costs is based.

So far as the relation of new types of locomotive (diesel-powered) or new proposal (gas-turbine) to railroad fuel consumption is concerned, there is almost certain to be a reduction in coal requirements.

A successful conclusion to the development now in progress could have these possible effects upon fuel use:

1. The development of a gas-turbine may show the way toward modification of the original design to use fuel oil instead of coal, probably with less exacting liquid fuel specifications than the diesel engine.
2. Or it may reverse the current trend toward diesel-locomotive installation and then retain the use of coal.
3. It may point the way to a new type of power unit in marine and stationary installations as well as in locomotives.
4. The present trend toward new locomotive types, irrespective of the ultimate outcome of experiments with gas-turbine locomotives will almost certainly reduce the quantities of fuel used by railroads.

Automotive Fuels

The development of transportation by automobile may prove eventually to have been one of the most significant stimuli in the technology of fuel preparation and toward widening the application of power to other areas of economic activity.

Automobile transportation currently (1946) uses 600,000,000 bbl of motor fuel. This is divided among major consumer groups as follows:

Passenger cars and buses	443,000,000 bbl
Trucks	135,000,000 bbl
Non-highway use	77,000,000 bbl

Fuels in Agriculture

Agriculture in the last two or three decades has received a sharp jolt, by reason of mechanization. In these decades animal power on farms declined from 6,676,704 work animals in 1920 to 3,637,885 work animals in 1940, and 2,800,000 work animals in 1945. This released 14,000,000 acres of farm land more or less hitherto set aside for animal forage. The key factor in the farm mechanization is the tractor but this is only part of the story.

Production per farm worker has been doubled since 1910 as a result of mechanization and the application of power. Since mechanical power in its earlier stages was best adapted to large farms, the large farms gained in efficiency much faster than the small ones. Machines are now being developed for small farms as well, and these farms may be expected to make more rapid strides toward increased output per worker.

The fuel requirements of agriculture embrace fuel for home heating, fuels for self-propelled mobile power units, portable or stationary engines, and electrical energy for power and light in the home and on the farmstead. Mobile power equipment consists of automobiles, motor trucks, tractor and portable gasoline engines. Coal burning steam engines are rare and declining in number. The mechanization of agriculture is being accomplished with the aid of power machinery fueled by gasoline, kerosene, or diesel oil.

Advances in power machines and their application to farm operations is expected in three general directions:

1. Design and production of new machines for work in crops where full mechanization or most economical mechanization has not yet been achieved. Three machines, recently developed by a leading manufacturer, illustrate these — the automatic, one-man, pickup hay bailer; the mechanical cotton picker; and the mechanical beet harvester.

2. Small tractors and tools for the smaller farms. An overwhelming proportion of the farms still without mechanization are the small farms where mechanization heretofore has not been thought to be economical.

3. The third direction in which mechanization is being expanded for the greater advantage of farm operation is in the adaptation of present or modified machines to new uses on farms. One such use is the adaptation of farm tractors and machines to soil-conservation work, particularly terracing. There are other new adaptations. Posthole digging and tree-planting are two examples.

Fuels in Construction

The varied types of activities grouped under the general term of construction are probably the least mechanized in terms of installed horsepower per worker or of quantity and tonnages of material handled mechanically. Among the tasks connected with construction activities which lend themselves most readily to mechanization are excavating, haulage of materials, moving earth, grading, hoisting, concrete mixing, etc. The power equipment adaptable to such tasks includes bulldozers, tractors equipped with shovels, post-hole augers, trenching machines, or portable engines operating air-compressors, snowplows, mixers, hoists, etc. A large number of trucks usually classified as transportation equipment are engaged exclusively in hauling sand, gravel, or stone from quarry or railroad siding to the construction job and are therefore, in fact, power units used in the building industry. The dominant form of power unit, whether large or small, self-propelled or portable-stationary, is the internal combustion engine. There are no estimates of the fuel consumption in construction activities; the only approach to an estimate that can be made is, by difference, after all other uses have been accounted for out of the total available supply of fuel. The quantity of fuel used is apparently not large, yet power equipment now plays a necessary role in construction, and on that basis liquid fuel supply is a necessity.

Fuels for Domestic Heating

The fuel requirements for domestic heating and other retail outlets such as small business establishments aggregate from 112 million tons of coal or its equivalent in a year of low use to 185 million tons of coal equivalent in a year of high use. Coal (anthracite and bituminous), fuel oil, and natural gas are the principal fuels, though wood is also used in rural districts, and also in urban centers in some Western states. A decade of consumption of fuels in this market as indicated by retail deliveries, gives a rough indication of the quantities and relative importance of each fuel.

Fuel for an Industrial Economy: a Recapitulation

A review of the nature and characteristics of our fuel and power supply discloses the high degree of fuel preparation and specialization and the many types of power machines needed to enable the economy to function. Almost every consumer good or intermediate product that we wish to name requires somewhere in the production process the services of a blast furnace, an electric motor, a locomotive, an internal combustion engine, a tractive unit, each varying in size and fuel requirements. Fuels in solid, liquid, and gaseous form and nonmaterial forces (electricity) ranging from the highly prepared coke or gasoline to run-of-mine coal are required to fuel the multitudinous types of engines.

Moreover, the sum total of all productive activities needed to carry the process to the final stage of a consumer good, requires the employment of several forms of power equipment and fuels. The activity, for instance, which sets in motion a demand for the employment of electrical power also sets in motion a demand for several kinds of transportation units and for the particular type of fuel required in each case.

A characteristic of an expanding and evolving industrial economy is the increase in the exacting requirements of materials and fuels essential to the functioning of the productive process. From a few materials or types of prepared fuels and power forms, an industrial economy is constantly becoming more and more inclusive in its material requirements if it is not to stagnate and wither. High productivity is not only a result of power application but a continual widening of the realm of power application and an increasing efficiency of power use. This results in a multiplicity of power and fuel forms and a specialization leading to exclusiveness in fuel forms to an increasing number of power appliances in an enlarging and evolving technology.

Although there is a considerable flexibility of fuel choice in manufacturing, power production, transportation, and domestic and retail use, there are nevertheless certain industries or industry groups which are exclusive in their fuel requirements. The distribution of fuels, by type and quantity for principal users, is shown in Table 4. Liquid and gaseous fuels have been converted to approximate coal equivalent. Hydroelectric power has been equated on a basis of 1.3 lb of coal per kw-hr.

An inspection of the table reveals some rather interesting and significant characteristics of fuel use in the United States. Liquid fuels have practically removed coal from the bunker fuel market. Only a small part of the total fuels used are converted into electrical power and, also, the coal equivalent contribution of water power in the production of electricity is small.

TABLE 4
FUELS USED IN PRINCIPAL GROUPS OF USERS: 1944*

	Bituminous Coal	Anthracite	Liquid Fuels	Natural Gas	Hydroelectric Power Coal Equivalent
	000 Tons	*000 Tons*	*000 Bbls*	*Million cu ft*	*000 Tons*
Collier fuel and bunker fuel	4,271	......	105,256	......	......
Electric power utilities	78,887	3,427	40,313	360,000	48,000
Land transportation, railroads, motor cars, tractors	132,049	1,094	710,769	......	......
Coke ovens and gas retorts	106,841	......	......	......	......
Manufacturing	136,987	5,000	103,617	1,702,000	......
Domestic and retail	132,795	51,885	158,822	782,930	......
Military needs	(a)	(a)	144,226	(a)	......
Used at mines or oil fields	6,066	......	56,394	855,000	......
Total	604,442	61,406	1,319,347	3,699,930	......
Total as approximate coal equivalent	......	61,406	329,837	148,000	48,000

* Source: *Minerals Yearbook.*
(a) Not available.

In land transportation, the item of current interest is the recently developed competition between the oil-fueled diesel locomotive and the coal-fired steam locomotive. Approximately one hundred million tons of coal is at stake in this competitive battle. The large portion of coal used in the manufacture of coke indicates the important role of fuels in the reduction of iron and other metals from the natural state.

In perspective, three characteristics of the fuel supply emerge as distinctive.

The first is the large requirements of a specially prepared fuel for the smelting of iron ore to the free metal. That this crucial operation in an industrial economy is altogether dependent upon one fuel form, carefully prepared and available only from a limited portion of the coal resources, focuses attention upon the question of adequacy of supply. The problem of coke supply is, in reality, the problem of iron supply; for coke is prepared specifically for the reduction of iron ore and, outside of this function, possesses no distinctive functions that cannot be performed by some other less elaborately prepared form of fuel.

A second distinctive feature of the American economy is the high preparation and the wide range of fuel requirements entering into the transportation industry. Almost 25 percent of the coal output and 50–55 percent of the crude petroleum output are so used.

A third is the increasing importance that liquid fuels have assumed. From a coal oil substitute for candles to oil lamps in lighting houses, liquid fuels have taken on one function after another and have been the deciding factor in the mechanization of some entire industries. The fear of a shortage has cast a shadow on the uses of oil. The threat of short supplies of this fuel has been removed by adding coal and natural gas to petroleum among the raw materials of nature from which liquid fuel can be obtained.

Liquid fuels are exclusively essential in the mechanization of agriculture and construction and in adding versatility to a large segment of the transportation functions. The transformation of agriculture, in a large degree, from animal power to mechanical power, and the accompanying increase in agricultural productivity, have been accomplished only with the aid of the internal combustion engine. Until liquid fuel became generally available, this addition to economic productivity in the agricultural realm was severely restricted. Gasoline and diesel fuel afford a variety of power application in agriculture and transportation comparable to those that electric power and the electric motor do in manufacturing.

IV. COAL HEATING STOVE MARKETS AND DEVELOPMENTS

HENRY N. OSTBORG*

One of the greatest challenges that coal producers and retailers must meet today is the coal heating stove market. How many of you here can answer such questions as: How large is this market? Where is it? What share of my retail coal business does it represent? What must be done to retain it? Only in recent years have the coal and stove industries attempted to answer these questions.

Coal Heater Market Size

How large is the coal heater market? The only available authentic data, unfortunately, are those compiled by the U. S. Bureau of Census in 1940. Recent information, particularly the "Facts for Industry" series of the Bureau of Census, lists yearly heater shipments but gives no indication of the yearly shift in dwelling units that are space heated.

In 1940 there were over 34 million dwelling units in the United States reporting heating equipment, of which 46.6 percent were space heated and 42 percent were equipped with central heating plants. Of the 19 million space heaters in use, approximately 7½ million (38.6 percent) were designed for coal and/or coke.

Industry shipment data from 1943 on indicate at first glance a relatively rapid decline of the coal heater market, which fell from 81 percent of total heater shipments in 1943 to 21 percent in 1947. These facts are somewhat misleading, however, as wartime restrictions placed upon manufactures of gas and oil fired space heaters lend undue emphasis to coal heater shipments for those years. Thus, it is interesting to note that accompanying a decrease of 34 percent in industry coal heater shipments as based upon total heater shipments, in the last 20-year span there has been a slight increase in total coal heater unit shipments, from 1.27 to 1.34 millions. Using 1927 as a base period the coal and wood heater shipment index has risen to 105, while the oil heater index rose to 1153, the gas heater index to 406, and the total heater shipment index to 275. Though it is evident that the coal heater market has not been lost, it is equally apparent that this industry has not maintained its share of sales when compared to the phenomenal sales increase of gas and oil. The reasons

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for increased customer acceptance of gas and oil heaters will be covered in detail later.

Unfortunately no figures are available covering the rate of displacement of coal heaters by those designed for either gas or oil. Unquestionably some displacement has taken place, but at the same time sufficient new installations have been made to maintain approximately the shipment level of ten and twenty years ago. Indications are, however, that it is in the new market — composed of the thousands of small homes built to house the returning G.I.'s and to accommodate the mass population shifts which took place during the war years — that coal heaters have lost the most ground.

No attempt will be made at this time to predict what is going to happen this winter, or in the next few winters, to the oil and gas heater markets. It is common knowledge that the high oil prices and shortages experienced last year and anticipated this winter should have a beneficial effect on coal heater sales. The results of a recent survey published in *Fuel Oil and Oil Heat* on "Consumers' Opinions on Fuel Oil" are indicative. This survey, conducted through 32 states primarily in the northern section of the country, showed:

1. Three-fourths of all coal users say that they have not, within the past year, considered switching to oil.
2. Of the remaining quarter who considered changing to oil in the past year, two out of every three have abandoned the idea and will stick with coal.
3. The chief reasons for the loss of interest in oil by those who recently favored it are fear of another shortage, and the high cost of oil.

The fuel oil appliance industry has become cognizant of the threat to their market, and it can be assured that they will attack this problem with the same vigor and intelligence that resulted in the recent rapid growth of oil heater sales.

In many areas, gas is the cheapest space heating fuel. In Pittsburgh, for example, the center of one of our greatest bituminous coal producing areas, it costs approximately 15 percent *less* to heat with gas than with coal. Drastic restrictions, however, have been placed and probably will be maintained for some time on the installation of gas heating equipment because of limitations of handling peak loads, thus fostering the use of coal heating equipment.

During the summer months coal heater sales have been slow and inventories high. This has been true in other fuel lines also, as the public has been waiting for information concerning fuel availability before making its heater selection. The increase in the price of coal, now at an index of approximately 150 calculated on a base period of October 1922 through September 1925, has contributed toward the general indecision of the public. Recent sales trends, however, indicate a satisfactory consumer acceptance of coal as a space heating fuel for at least the coming winter.

Location of Coal Heater Market

Where is the coal heater market located? A general answer is "Everywhere throughout these United States." Examination of the 1940 Census national-user figures show that in 45 states coal and wood were the fuels most widely used for space heating. Coal alone was the No. 1 fuel in 24.

It has been a general misconception that rural and southern areas constitute the greatest users of coal fired space heaters. The 1940 Census data show that 32 percent of the coal heaters in use were located in four states, all in the northern section of the country — Pennsylvania, Illinois, Ohio, and New York. It has been estimated that two out of every five dwelling units north of the Ohio River are stove heated.

Certainly the coal heater market cannot be considered strictly a rural market when metropolitan Chicago has 228,000 coal heater installations — one-third of the total number of coal heaters in the state of Illinois — and when metropolitan Pittsburgh with 100,000 coal heaters represents one-seventh of the total number of heaters in the state of Pennsylvania, the leading state in the use of coal heaters.

The earning power of the American people in the past few years has been higher than ever before; and, because of the inability to purchase many desired items, savings have also been high. When rationed merchandise returned to a free market, consumer savings were spent on purchases of premium items, evidenced in the coal heater line by unusually heavy sales of top-line numbers. This has been one of the contributing factors in the rapid growth of oil and gas heater sales. Recent sales trends indicate a gradual return to a normal market, because of savings dissipation and consumer wariness, wherein fuel economics and availability as well as heater price will again be an important factor in heater selection. Thus the coal heater market is not and should not be considered localized, and areas wherein coal can be produced and sold cheaper than competitive fuels will be the major areas of coal heater sales. For example, the Southwest region, rich in natural resources of gas and oil, is not the potential sales area for coal fired space heaters that we find in the coal producing states of Illinois, Indiana, Ohio, and Kentucky.

Share of Retail Coal Market

What share of the retail coal business does the coal heater market represent? In 1940 approximately 123 million tons of coal, including anthracite, bituminous, and coke, were sold for home heating. Assuming a conservative average consumption of four tons of coal per space heater per heating season, 30½ million tons, or 25 percent, of the domestic retail coal sales were made to users of coal fired space heaters. Based on an average price of $10 per ton this means a total sales volume of over 300 million dollars on the retail level. There are no indications of a shrinkage in dollar volume of coal consumed in heaters last year, though the percentage in total retail sales may be down slightly.

Assuming that coal heater sales do decline rapidly, not only in percentage of total heater shipments but also in unit shipments, there are two problems that coal producers will have to solve which will have a direct bearing upon coal market price and distribution. First, some of the coal formerly used by the coal heater users will have to be resized for industrial sale or for use in domestic stokers. This increased handling will necessitate a higher selling price or increased sales volume, or else lead to a lower gross profit to all concerned. Second, resizing will raise the problem of what to do with the increased quantities of $-5/16$-in. size resulting from extra crushing.

Coal Heater Developments

"Old King Coal" is no longer the merry, complacent ruler of the heating industry of yore. Rapid technological steps taken by competitive fuels have outdistanced the coal and coal burning appliance industries who have until recently been relatively content to rest upon their laurels. What has been done and what must further be done to retain the coal heater market?

With this question in mind, other points of interest from the previously mentioned survey on "Consumers' Opinions on Fuel Oil" are:

1. Seventeen percent of the users of oil for home heating wanted to change to some other fuel mainly because of the recent oil shortage or fear of another shortage or because of the expense of oil.

2. For the 83 percent who did not wish to change from oil to some other fuel, the principal reasons for sticking with oil were:

   a) Convenience
   b) Cleanliness
   c) Heating efficiency
   d) General satisfaction.

A realistic approach to the problem definitely must be made, wherein the disadvantages as well as the advantages of coal heaters versus heating with oil or gas must be known. Let's examine individually the four reasons listed above by those people using oil in preference to coal.

Convenience

The intangible factor of convenience is definitely adverse to the use of coal for space heating in the minds of the general public. They have been taught, partly by experience, that coal is dirty to handle, that the resulting ash and fly ash is messy and inconvenient, and that gaseous products of combustion escaping into the living quarters at times of refiring are extremely obnoxious. What can be done to combat these factors?

First, research has shown us that oil or other materials can be added to coal to reduce dust and dirt in handling. Briquetting or packaging methods can be employed that will reduce handling dirt to a minimum.

Second, there is no conceivable method of eliminating the ash present in coal at the time of its use in the home. Improved methods of coal preparation, however, can decrease materially the ash content of coal prior to sale on the retail market. Also, heater design changes for improved methods of ash storage and handling should lead to increased customer satisfaction.

Third, improved heater design and methods of fuel burning can be devised to reduce to a minimum the coal gases escaping into the living quarters, even under the most careless methods of refueling.

Cleanliness

The factor of cleanliness has been treated in part under the subject of convenience, but is of sufficient importance to require additional emphasis. Cleanliness of fuel use not only pertains to the actual burning within the home but also has a direct bearing on home deliveries. Thus, it is not only the duty of the heater manufacturer to improve heater design, but also is the responsibility of the coal retailer to improve the cleanliness of home delivery methods and equipment.

Heating Efficiency

Improvement of heater efficiency is distinctly a matter of heater design and thus is a problem to be solved by the heater manufacturer. Fortunately, the coal industry has recognized the need of solution and has entered the picture in a serious and logical fashion. More about this later.

What is the efficiency differential between coal and oil or gas? The efficiency for a vented gas heater must be 70 percent or better to meet AGA standards, and that of an oil fired heater must be 70 percent to meet Underwriters Laboratory Approval standards. There are no set efficiency requirements for coal fired space heaters, but dependent upon heater design the efficiency when burning a bituminous coal will normally fall in the range of 35–45 percent.

For an answer to the startling difference in efficiencies we must turn to an examination of the heat balance determined during a rating test. For all three fuels the commonest heat loss comes in the heat content of the dry flue gases. This loss could be reduced materially for all fuels by the use of increased secondary heat exchanger surface, and thus does not explain the drastic difference in efficiencies. In the heat balance for a coal fired heater, however, is introduced a factor of Unaccounted-for Losses that is not part of the heat balance calculations for gas and oil fired heaters. This unaccounted-for loss is that attributed to gaseous hydrocarbons and/or smoke that escape unburned up the chimney. It has been common practice to assign an arbitrary value of 20 percent to this loss, as there is no means of measurement without the use of a calorimeter room wherein the efficiency of a unit can be measured directly. The amount of this loss has been questioned recently, and research is under way to determine a factual value. Nevertheless, it can be seen that, if this loss for coal could be reduced by improved methods of burning, the efficiency differential between coal and its competitive fuels could be drastically narrowed.

General Satisfaction

The discussion of general satisfaction is one extremely difficult to rationalize, as some people can never be convinced of the merits of one fuel versus another because of previous use association. It stands to reason, however, that this factor is completely dependent upon other general improvements, and only if, and it's a big if, these improvements are realized can general customer satisfaction be anticipated.

Recent Developments

In the past few years considerable research work has been done to improve the operational characteristics of coal fired space heaters. Probably the most widely publicized is the development of a smokeless coal heater by Battelle Memorial Institute, the work being jointly sponsored by Bituminous Coal Research, Inc., and a group of twenty-seven stove manufacturers. Other research organizations have been working on similar lines, notably the University of Illinois.

The BCR program is extremely heartening because at long last the coal and stove industry are working together for the solution of mutual problems. Their development of the smokeless heater has reached the trial production stage to ascertain public acceptance, and is definitely in tune with the movement of many of our cities to rid the air of smoke and pollution. Many of you may already know how well this heater has done the job it was designed to do, and how much it has narrowed the unit efficiency gap between coal heaters and those designed for use with gas and oil.

It is sincerely hoped that joint work of this nature will continue to the point where coal heaters will have more factors in their favor other than savings in initial fuel costs. This goal *can* be realized and should not be too far away.

Future Needs

Both oil and gas heaters have definite efficiency requirements as set up by the industry and controlled by independent testing organizations. These approval requirements go even further than efficiency, and stipulate constructional and other functional limitations. Thus, a purchaser of a gas or oil heater is assured that the heater design he selects has been approved on the basis of certain set industry standards.

Unfortunately the coal heater industry has no accepted approval standards of any type. The U. S. Bureau of Standards at one time attempted to formulate a rating procedure and structural standard for coal fired heaters. This was not accepted by the industry, primarily because the testing fuel was anthracite rather than a bituminous coal, and thus a true picture of heater performance could not be obtained for the greatest preponderance of units sold. Independent work is continuing on the formulation of a testing procedure, however, and it is hoped that soon one will be devised that will be acceptable to the entire industry.

Another need within the coal heater industry is for trained technical men in order to evaluate the performance of existing merchandise and to assist in planning future developments. This lack of technical personnel obtains in the gas and oil heater industry as well. Trained combustion engineers are relatively few in the entire stove industry, and considering the size of that industry considerable opportunity is offered to young men desiring to enter this field.

A factor of consumer acceptance in which the coal industry can aid tremendously is service, covering heater installation and also stovepipe and chimney construction and condition. A coal heater is no better than the chimney to which it is connected. Too often a heater is criticized for failure when the fault is with the chimney. The coal retailer is in an admirable position, because of repeated customer contact, to influence not only coal selection but over-all heater satisfaction as pertaining to safety and performance.

It Can Be Done

The coal heater market of tomorrow does not look overly bright today; but it does appear considerably brighter than yesterday. Recent technical developments have shown that many advantages of the so-called "convenience" fuels can be not only matched but in some instances exceeded. For the coal heater to assume its rightful economic position, however, considerable time, effort, and forethought must be expended.

Can it be done? The answer lies with the stove and coal industries, but I believe that it can. Heaters must be designed as strong, carefully built, efficient units that will give satisfaction to the best of our ability. This can be accomplished by: (1) maintaining staffs of technically trained men who will work closely with those responsible for building the heaters, (2) keeping abreast of the public demands, and (3) by trying to match the performance of gas and oil heaters.

With the information given concerning size of market and what it means to the coal industry in yearly dollar volume, it becomes obvious that the battle is worth the winning.

V. PRESENT STATUS OF THE DEVELOPMENT OF HAND-FIRED SMOKELESS COAL HEATERS

J. R. FELLOWS*

Some of the stove and furnace patents on file in the U. S. Patent Office indicate that inventors have been trying for nearly 100 years to develop practicable handfired smokeless coal heaters. However, the fact that there was no such equipment on the market when the studies at the University of Illinois which led to the development of the Illinois Smokeless Furnace were begun in 1935, constituted prima facie evidence that some of their problems had not been solved. Later, in 1941, a separate investigation was started at Battelle Memorial Institute in Columbus, Ohio. This project, which has the same objectives as the one previously mentioned, is under the joint sponsorship of Bituminous Coal Research and a group of stove manufacturers.

Due in large part to the cooperation of the National Warm Air Heating and Air Conditioning Association, two individual furnace companies, and a manufacturer of firebricks, the Illinois Smokeless Furnace has now been developed through the many necessary stages from the conception of the incorporated design principle to the actual production and sale of commercial units. The furnace is now offered for sale by an organization that is national in its scope. Likewise, the BCR Stove which has been developed at "Battelle" is now being produced commercially by several of the stove companies which contributed funds toward the support of the project.

Illinois Smokeless Furnace — First Design

Although several preliminary experimental furnaces were designed, constructed, tested, and then discarded, the furnace which will be referred to in this paper as the "first design" is the first specific arrangement of parts that was actually used for heating a residence. Figure 1 shows a vertical sectional view of this arrangement. The principal parts are labeled, and the fuel bed is shown in the condition which would exist immediately after the placing of a charge of fresh coal. The baffle wall, the vertical secondary air passages, and the combustion flues are formed by special refractory units, a detail of which is shown in Fig. 2. Each baffle wall unit or section is composed of two matching E-shaped bricks which, when in position, are

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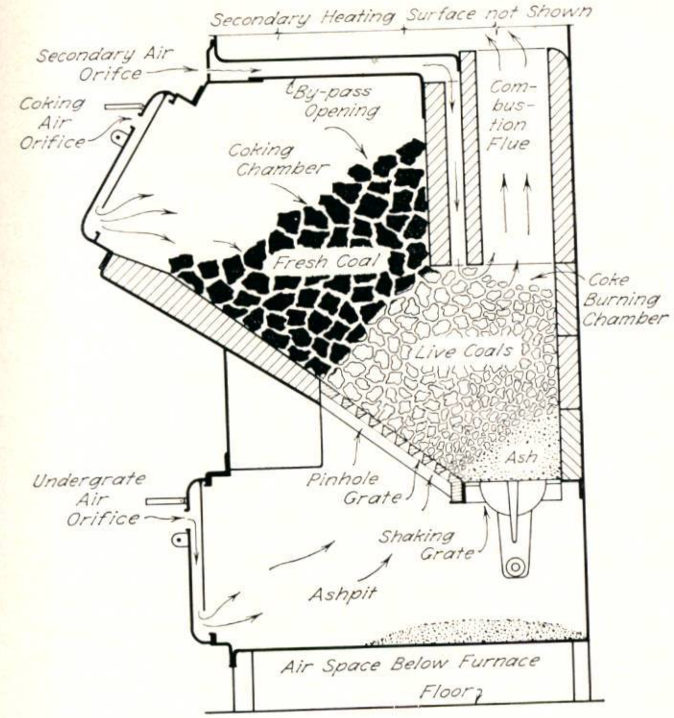


FIG. 1. CROSS-SECTION OF FIRST DESIGN

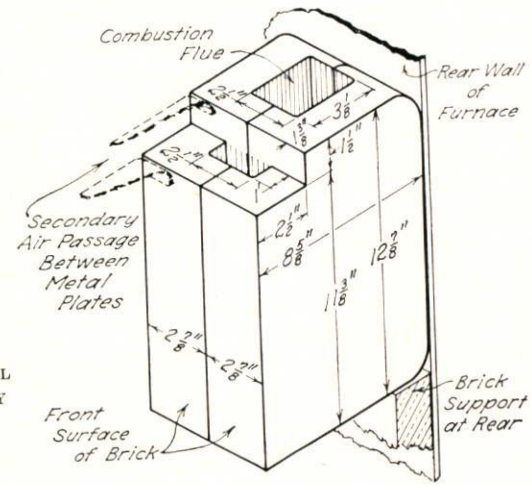


FIG. 2. DETAIL OF REFRACTORY UNIT

supported at the bottom by the firepot lining and at the top by two horizontal metal plates which form the secondary air passage. The inside width of the furnace is determined by the number of baffle wall sections required.

Each charge of fresh coal is converted to coke in the coking chamber at the front of the furnace while that converted from the previous charge is burned in the coke-burning chamber at the rear. The volatile matter released as a gas from the fresh coal mixes with the secondary air introduced through the vertical air passages adjacent to the combustion flue. The mixture passes over live coals in the coke-burning chamber, where it is ignited. The burning is then completed in the combustion flues.

The rate of release of gases from the fresh coal is governed by the amount of air admitted to the coking chamber, and the rate at which the coke is burned is determined by the amount of air passing into the ashpit and through the grates. The orifice in the firing door and the one in the ashpit door are so proportioned that each charge of fresh coal is converted to coke before that from the previous charge is completely burned.

A more detailed description of this furnace, together with a thorough discussion of the results obtained in both laboratory and residence tests, is included in Illinois Engineering Experiment Station Bulletin No. 370.[1] A part of the following discussion which pertains to these tests has been extracted from that bulletin.

A series of tests was conducted in the laboratory to determine the burning characteristics of a wide variety of solid fuels. The furnace used in this test included 3 of the baffle wall sections illustrated in Fig. 2. The coal samples, weighing from 200 to 400 lb, differed widely with respect to such properties as moisture content, volatile matter content, ash content, ash fusion temperature, and friability of coke formed.

The following general conclusions, based on the experience obtained in the laboratory tests, may be drawn with respect to the burning characteristics obtained with different solid fuels:

a) Fuels having a range of volatile matter content of from 1.5 percent to 41.9 percent were satisfactorily burned.

b) Coals having a high ash content introduced no difficulty aside from the inconvenience of removing greater amounts of ash. From the standpoint of hold-fire characteristics, in fuels having a high ash content the ash served to insulate a small bed of hot coals and thereby

[1] "The Illinois Smokeless Furnace," by Julian R. Fellows, Alonzo P. Kratz, and Seichi Konzo. 1947.

tended to increase the possible length of the hold-fire period.

c) Bituminous coals having ash-softening temperatures ranging from about 1900 to 2800 deg F were burned without formation of slag or clinkers.

d) Coals ranging in size from ¼ in. by ¾ in. to 3 in. by 6 in. were satisfactorily burned. However, it was found that strongly coking coals did not coke thoroughly in the center of the charge if a large proportion of the pieces was less than 2 in. in diameter.

A 3-section furnace practically identical with the one used for the laboratory tests was installed in a Warm Air Heating Research Residence[2] in the fall of 1943. After serving the residence during the greater part of the winter of 1943-44 the 3-section furnace was replaced by a 4-section unit of the same type. The larger furnace was installed during the month of March 1944 and was tested during the rest of the spring of 1944 and throughout the entire 1944-45 heating season.

Throughout the period of the tests which were conducted in the Research Residence, continuous records were made each day of the CO_2 content and temperature of the flue gases at the smoke collar of the furnace. Arithmetical averages of both the CO_2 content and the flue gas temperature for each 24-hr test period were obtained from the records and plotted against the difference in temperature between the indoor and outdoor air as shown in Figs. 3a and 3b. It may be observed that both the percentage of CO_2 and the temperature of the flue gases increased as the weather became colder. A comparison of Figs. 3a and 3b indicates that for a given indoor–outdoor temperature difference, the CO_2 content and the flue gas temperature were both greater for the 3-section furnace than for the 4-section. For example, at an indoor–outdoor temperature difference of 38 deg F the CO_2 content and flue gas temperature were 7.6 percent and 420 deg F respectively for the 3-section furnace, and 6.3 percent and 260 deg F for the 4-section. The latter was equipped with a greater amount of heating surface than the 3-section unit. Hence, for a given hourly fuel consumption a greater transfer of heat occurred from the flue gas to the circulating air, and as a result lower flue gas temperatures were obtained. The percentages of CO_2 shown in Figs. 3a and 3b are arithmetical averages including both on-period and off-period operation of the furnace. The slightly lower CO_2 values shown from the larger furnace probably resulted from the fact that a proportionally larger amount of secondary air was supplied during

[2] Described in "Investigation of Warm Air Furnaces and Heating Systems," by A. C. Willard, A. P. Kratz and V. S. Day, Univ. of Ill. Eng. Exp. Sta. Bul. 189.

off-period operation. Also, the larger furnace operated with longer periods of closed dampers than did the smaller.

The losses due to sensible heat and water vapor in the flue gases at the smoke collar, represented by the top set of curves in Figs. 3a and 3b, were practically constant over a wide range of indoor–outdoor temperature differences, and amounted to approximately 21 percent for the 3-section furnace and 16 percent for the 4-section. These losses, expressed as a percentage of the heat liberated in the furnace, were estimated from generalized curves presented in Illinois Engineering Experiment Station Circular 44. They did not include losses resulting from unburned combustible in the ash and refuse. The latter amounted to about 5.5 percent of the heat liberated for the 3-section furnace and about 4.6 percent for the 4-section. Hence the total losses, including those due to sensible heat and water vapor in the flue gases and to combustible in the ashpit, were about 26.5 percent and 21 percent respectively for the 3-section and 4-section units. The corresponding combustion efficiencies, defined as 100 minus the total losses, were about 73.5 and 79 percent respectively.

Although this type of furnace performed satisfactorily in the Research Residence and in many private homes, there was in every case a noticeable loss of coke through the grate and it was difficult to transfer the newly formed coke from the coking chamber to the coke-burning chamber when burning a strongly coking type of coal during extremely cold weather. Further development of the first design was discontinued in 1945 and work was begun on the second design, which is described in the next section of this paper.

Illinois Smokeless Furnace — Second Design

Figure 4 is a sectionalized view showing the interior construction of the second design as it is now manufactured by the furnace company which has borne the expense of its development and is pioneering its introduction to the public. Figure 5 is a vertical cross-sectional view showing the various parts of the furnace in their proper positions in the complete assembly.

The second design incorporates the downdraft coking principle of smokeless combustion that was used in the first design, which has been described. A round body has been substituted for the square one, the inclined pinhole grate has been eliminated, the shaking grate has been expanded so as to extend under the entire firepot, and the baffle wall has been simplified. The secondary air is brought into the furnace through a tube extending through the casing from the back of the firepot, from which it passes into the perforated

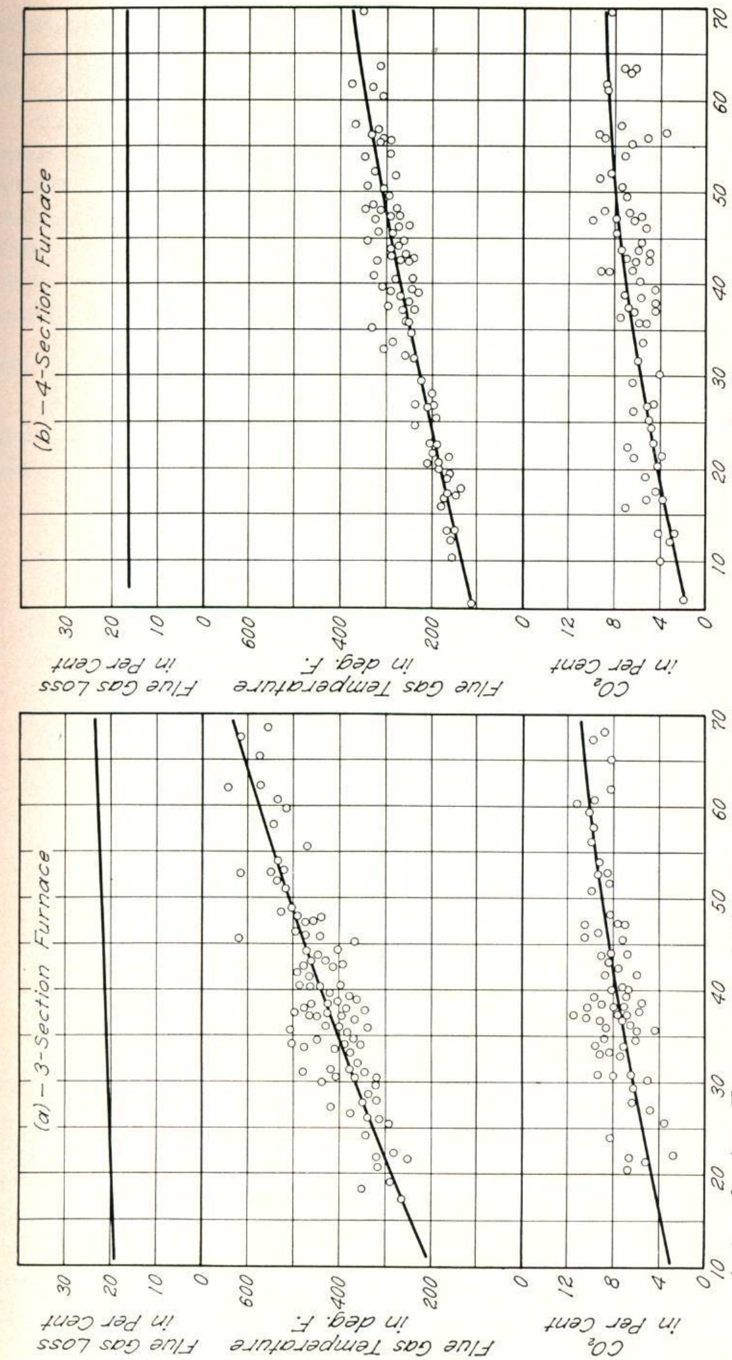


FIG. 3. FLUE GAS LOSSES FOR 3-SECTION AND 4-SECTION FURNACES

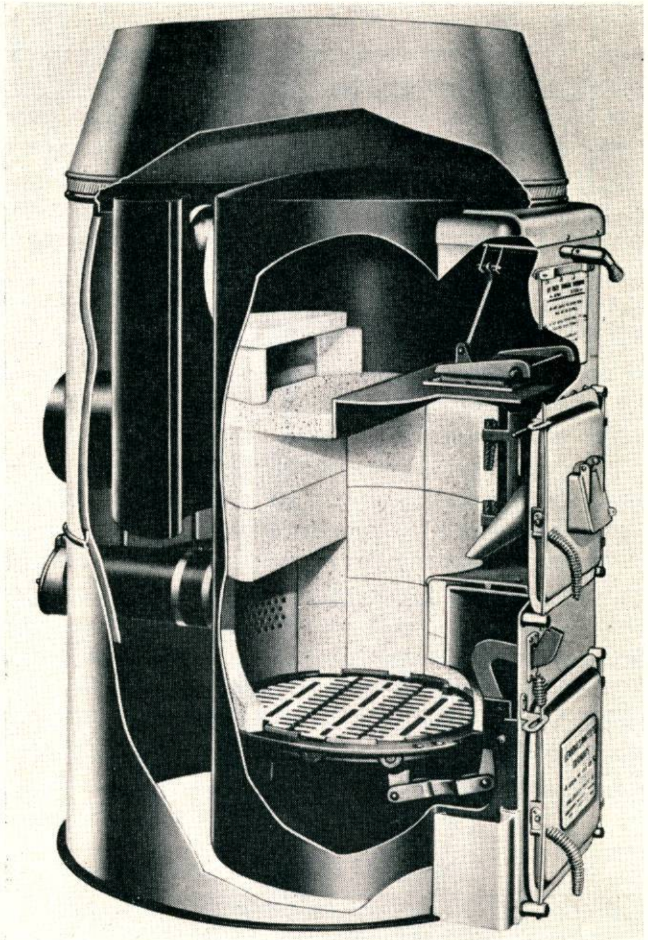


Fig. 4. Sectionalized View — Interior Construction of the Second Design

channel, then through the holes in the channel into the mixing space directly below the combustion flue. The primary undergrate air enters the perforated channel along with the secondary air, but from that point it passes through the metering slots in the edge of the grate ring at the base of the channel, into the ashpit. The secondary air and the undergrate air are properly proportioned because the total area of the holes in the channel bears the correct relationship to the total area of the slots in the grate ring. The coking air which

supports the combustion in the fresh fuel and causes the volatile matter to be gasified is handled in essentially the same way as in the earlier design.

The only fundamental change is in the manner in which the secondary air and the primary undergrate air are metered and delivered to their respective points of usage. It was expected that the revised furnace would operate in a manner practically identical with that of the earlier design. The advantages in the revised construction consist of decreased manufacturing cost, better grate efficiency, and simplified firing technique.

Operating Principle Similar to That of Underfeed Stoker

In either type of the Illinois Smokeless Furnace, smokeless combustion is achieved by placing the fresh coal in a separate coking chamber, where the rate of gas release can be controlled, leading the

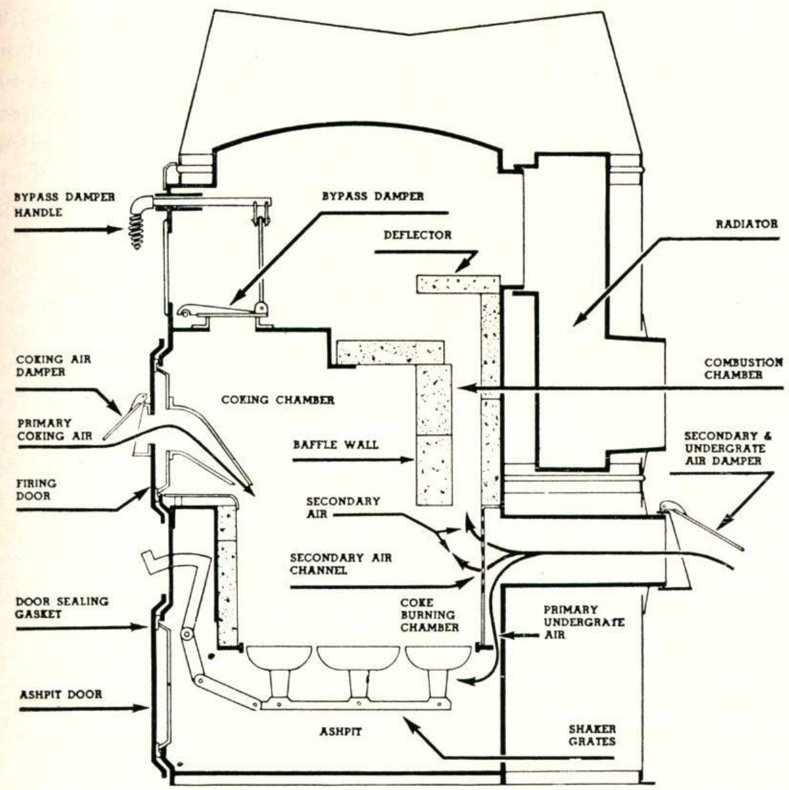


Fig. 5. Vertical Cross-Sectional View of Complete Assembly

released gases and the secondary air to a mixing chamber, and providing an ignition surface in the mixing chamber in the form of burning coke. Smokeless combustion is achieved in the underfeed stoker by feeding the raw coal into a small coking zone as needed, blowing air into this same zone, and providing a layer of burning coke directly above the point where the gas and air are mixed. The basic principles of smokeless combustion are employed in a similar manner in each of the two devices. One is designed to accomplish the desired results through mechanical means, whereas the other is arranged for handfiring.

Special Test of Second Design

A special test of the new type of smokeless furnace was conducted July 24–28, 1948 by the writer in the Mechanical Engineering Laboratory at the University of Illinois for the purpose of obtaining data of interest to those engaged in smoke abatement work. The furnace tested was identical with that shown in Figs. 4 and 5, which is now available to the public, except that it lacked some of the refinements in the details of the firing door and bypass damper which have been added by the manufacturer since the test unit was constructed.

The coal burned was a high-volatile bituminous type from Saline County, Illinois. The preparation used for the test was a nut size in which the lumps ranged from 1½ to 2 in. in diameter. The smoke density was measured and recorded by means of an instrument which utilizes the principle of a beam of light projected across the smoke pipe onto a thermopile located on the opposite side. If the beam of light is completely unobstructed the recorder indicates its zero reading, which is adjustable and depends upon the voltage applied to the light bulb that creates the beam of light. If the beam of light is completely intercepted by dense smoke in the smoke pipe the recorder gives a reading of 100 percent smoke density. During this test the draft was regulated by means of an adjustable cross-damper instead of the automatic balanced damper normally employed, in order that there might be no dilution of the products of combustion before they passed the station at which the smoke density was measured. The percentage of CO_2 was determined by a hand-operated flue gas analyzer. The temperature of the flue gas was measured by a mercury-filled glass thermometer having a range of 0–1000 deg F, and the draft at the smoke collar was measured with an inclined draft gage having a range of 0–1 in. of water.

The test extended over a period of approximately 100 hr and was so conducted that a smoke record was made of the furnace operation. Bituminous coal was burned at combustion rates which ranged from

the highest obtainable to the lowest that can be maintained without losing ignition in the lower fuel bed. The smoke recorder was placed in operation and the zero reading adjusted before the fire was kindled, and was maintained in operation throughout the test. Analyses of the flue gas to determine the percentage of CO_2 were made at frequent intervals (5 to 30 min) except at times during the tests conducted at extremely low burning rates, when the conditions of operation changed so slowly that frequent analyses were not necessary. Each time that an analysis of the flue gas was made, the flue gas temperature, draft, and smoke density were also recorded.

The test period in which the maximum possible burning rate was maintained followed the starting cycle, after which the combustion rate was reduced in each succeeding cycle until absolute minimum had been reached. The periods between firings ranged from 5 hr at the maximum burning rate to 24 hr at the medium and lower rates.

Smoke Records Taken During the Special Test

The primary objective of the test was to obtain data in regard to the effectiveness of the furnace in burning a high-volatile coal smokelessly. Photographic reproductions of the smoke records are shown in Fig. 6.

The 24-hr record in the upper left-hand part of the figure shows the density of the smoke that was produced in kindling a fire, in coking the initial charge of coal, in refiring, while operating at the highest possible burning rate, and while operating at a moderately high burning rate. In addition to the starting charge, which was ignited at point A, fresh coal was fired at points B, C, and D. The air dampers were continuously open between points A and C and the fuel was burned at a rate approximating 10 lb per hr. Between points C and D the dampers were alternately opened or closed as required in order to maintain an average burning rate approximating 6 lb per hr.

The smoke record in the upper right-hand portion of Fig. 6 is for a 24-hr period in which the dampers were alternately opened or closed as required in order to maintain an average burning rate approximating 3½ lb per hr. The smoke which appears at point A of this record was caused by placing a charge of fresh coal on a bed of coke which had been allowed to burn down well below the level of the bottom of the baffle. The momentary peaks which appear on the same record at points B, C, and D were caused by closing the dampers after allowing them to remain open until a high combustion rate had developed. Closing the dampers abruptly under this condition of operation causes a momentary shortage of secondary air because the volume of this air entering the furnace during a fixed time interval is decreased instantly to that which is admitted through the bleed hole in the damper, whereas the rate at which the gases are released decreases gradually.

The two smoke records in the lower part of Fig. 6 were made during the latter part of the test while the fuel in the furnace was burned at a very low average rate approximating 0.75 lb per hr such as might be required when a furnace is in actual service during early fall and again in late spring. While these two records were being made, small charges of fresh coal were fired at approximately 24-hr intervals. After each firing, the dampers were left open until a hot fire developed, after which they were closed throughout the remainder of the cycle.

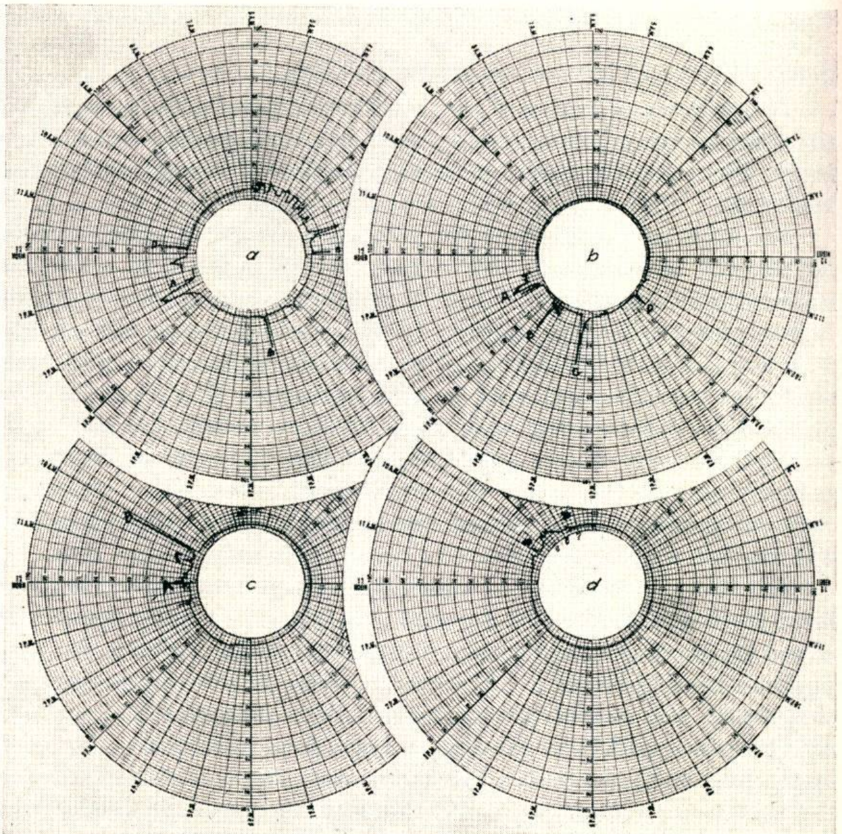


Fig. 6. Photographic Reproductions of Smoke Records from Special Test of Smokeless Furnace

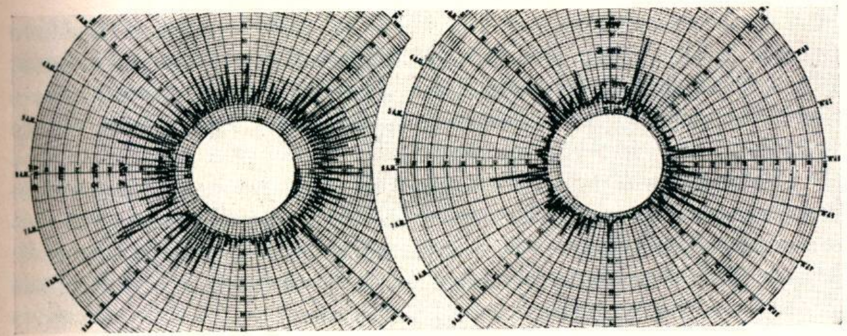


Fig. 7. Smoke Records of a Stoker-Fired Furnace

Small charges weighing approximately 18 lb were fired at points A and B on the lower left-hand record of Fig. 6. Previous to the time indicated at point A on this record the furnace had been operating with the dampers open, so that the small bed of coke was red-hot when the charge of fresh coal was placed. When the furnace was fired at point B on the same record and at point A on the one at the lower right, the greater part of the fuel in the furnace had lost ignition because of the extremely low burning rate through the latter part of the preceding cycle. At point B of the lower left record, considerable volatile matter was still present in the coke that was broken up and pushed back under the baffle, whereas no gas remained in the coke when the furnace was fired at point A of the record in the lower right portion of the figure. It may be noted from these two records that while it is impossible to fire the furnace under the conditions which are apt to prevail during early fall and late spring without producing some smoke, dense smoke is not produced, regardless of the condition of the fuel bed at the time the fresh coal is added.

Comparison of Smoke Records with Those from an Underfeed Stoker

Since smoke density is very difficult to measure on an accurate quantitative basis and since all persons engaged in smoke abatement work are thoroughly familiar with the performance characteristics of the underfeed stoker, it seems logical to compare the performance of the new furnace with that of a stoker-operated furnace under similar conditions as to burning rate and when burning coal produced by the same mine.

The left-hand portion of Fig. 7 is a photographic reproduction of a smoke record made on December 30, 1939, from a stoker-fired furnace in the Warm Air Furnace Research Residence in Urbana, Illinois. The conditions of operation when this record was made were high rate burning, as the outdoor temperature varied from −3 to +22 deg F during the 24-hr period.

The right-hand portion of Fig. 7 is a smoke record made from the same installation on November 3, 1939, and represents the performance of the stoker when operated at a medium burning rate. The outdoor temperature ranged from 30 to 40 deg F during the 24-hr period for which this record was made.

The smoke records of Fig. 7 were made with the same smoke recorder that was used in the tests of the smokeless furnace and were selected after a review of more than 100 similar records. Each is believed to be an approximate average for the type of weather condition it represents.

The results of the entire series of tests from which the records of Fig. 7 were selected have been summarized in two papers.[3, 4]

It may be observed that considerably more smoke was produced by the stoker-fired furnace than by the smokeless furnace under the conditions of high-rate burning. There was little difference in the amount of smoke produced by the two devices at moderate burning rates. The tests at the Research Residence were not started in the fall until the arrival of settled cool weather, and were concluded in the spring, with the advent of the first warm days. Therefore, it was not possible to find a smoke record for the stoker which would be comparable with the records for the furnace that are shown in the lower portion of Fig. 6.

The peaks in a smoke record from an underfeed stoker result when the fan and feedscrew are stopped after a period of operation. The momentary smoke production is caused by a shortage of secondary air, and the conditions are quite similar to those occurring in the handfired smokeless furnace when the dampers are abruptly changed from a wide-open position to one that is completely closed. In the case of the stoker, fresh fuel is continuously fed into the coking zone while the mechanism is in operation. The longer the period of operation, the greater is the rate of gas release at the time the fan is stopped and the longer will be the time interval during which there is a shortage of secondary air. It would therefore be expected that more frequent and more dense smoke emissions would

[3] "Performance of Stoker-fired and Hand-fired Warm Air Furnaces in the Research Residence," by A. P. Kratz, S. Konzo, and R. B. Engdahl. Trans. ASHVE, 1939, Vol. 45, p. 297.

[4] "Performance of a Stoker-fired Warm Air Furnace as Affected by Burning Rate and Feed Rate," by A. P. Kratz and S. Konzo. Trans. ASHVE, 1940, Vol. 46, p. 125.

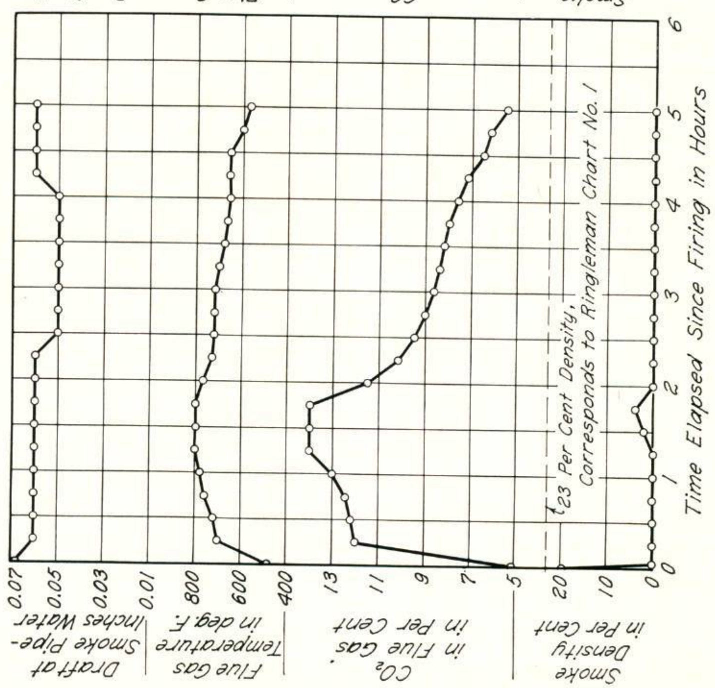
occur in colder weather, as is indicated by the cold weather and moderate weather records of Fig. 7.

Extremely low-rate burning was thoroughly investigated in the case of the smokeless furnace, as it is under this condition that the amount of smoke produced is most affected by the exact condition of the fuel bed at the time of firing and by the technique used by the operator. During moderate winter weather and during cold weather the best possible results may be achieved by applying a standard procedure (shake grate, poke down coke, and fill coking chamber) once or twice each 24 hr. The thermostat, through operation of the damper motor, will maintain a uniform room temperature at all times. The writer can see no reason why results comparable to those obtained for high and medium burning rates will not be duplicated in a home equipped with a furnace of this type during weather which requires burning rates in those ranges. However, in early fall and in late spring, when the outdoor temperature at any time may rise to 70 deg or above, it is necessary to leave a bed of ash on the forward part of the grate to prevent occasional overheating. The correct procedure in firing the smokeless furnace under these conditions of operation is to poke the ashes through the grate at the back of the firepot, push all available coke back against the air channel, and place a small charge of coal in front of the coke. The results of the tests clearly indicate that if this procedure is followed, little smoke will be produced and good results will be achieved regardless of whether the previous charge is completely coked and hot, completely coked and nearly "dead," or only partly coked and nearly "dead," at the time of firing.

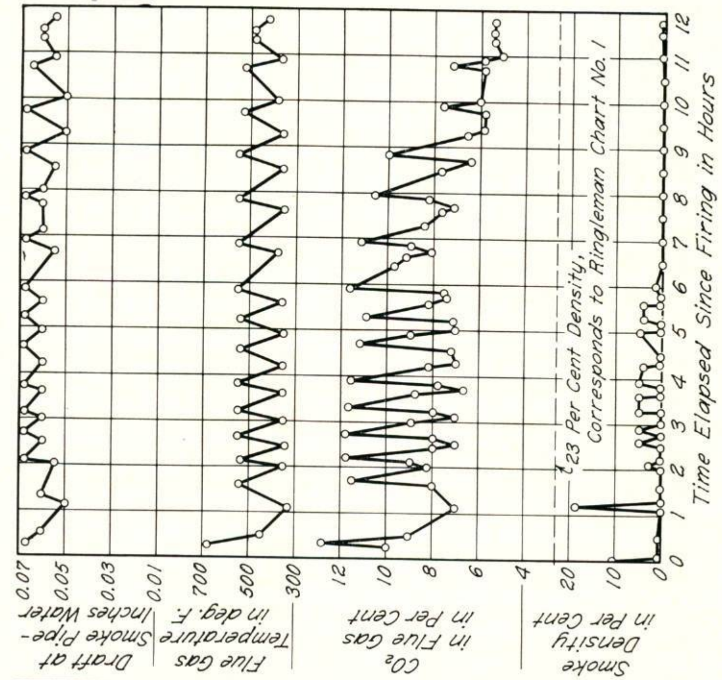
Significant Performance Data from the Special Test

Performance data recorded during the special test of the second design are shown in graphical form in Fig. 8. The data shown in Fig. 8a were taken while the fuel was being consumed at the maximum burning rate attainable with the amount of draft which was used. The average burning rate during the 5-hr period was approximately 10 lb per hr. The fact that the flue gas temperature did not exceed 800 deg F indicates that a furnace of this type cannot be overheated if it is installed with a draft regulator which limits the draft to an amount approximating 0.06 in. of water. It may be noted from these data that the proportion of CO_2 in the flue gas reaches a maximum of 14 percent when the furnace is fully charged and when a maximum burning rate is maintained for more than 1 hr after firing.

The data shown by the set of graphs appearing in Fig. 8b were

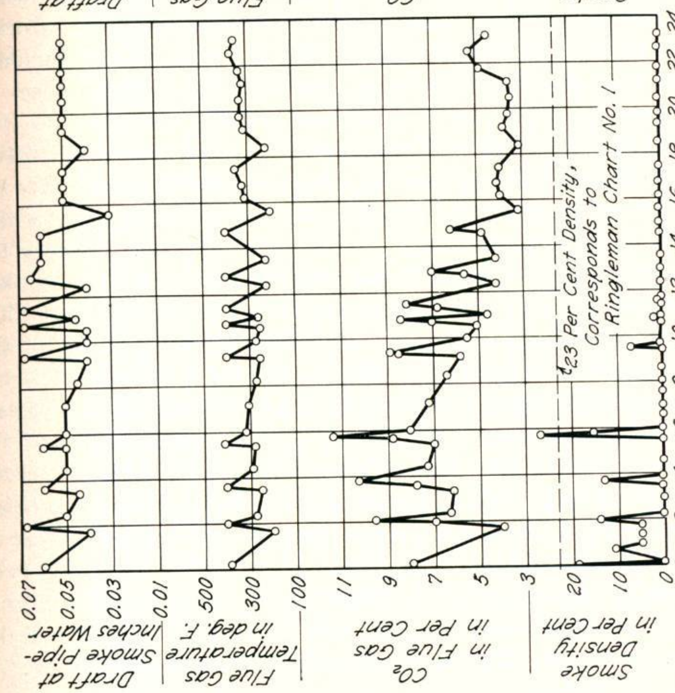


(a)-Maximum Burning Rate. Dampers Open Continuously.

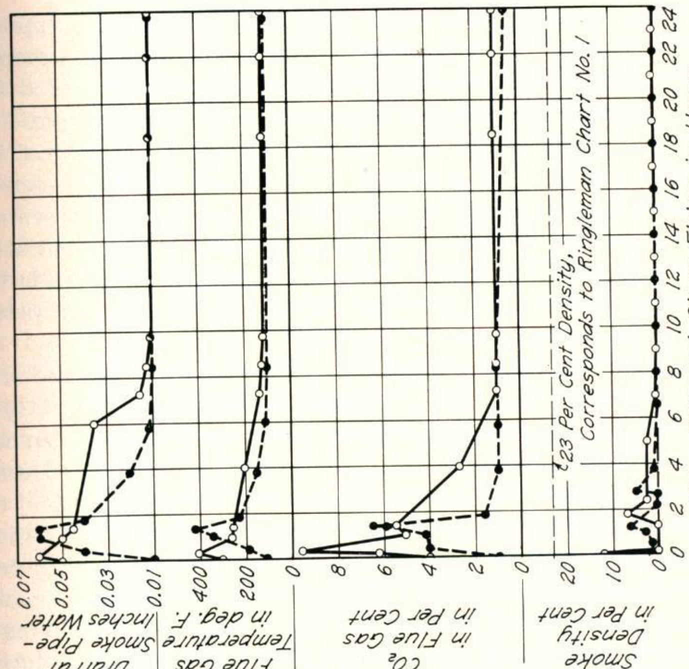


(b)-High Burning Rate. Flue Gas Temperature Maintained at an Average Value Approximating 450°F.

FIG. 8. GRAPHICAL LOGS SHOWING DATA TAKEN DURING SPECIAL TEST OF SECOND DESIGN



(c)-Medium Burning Rate. Flue Gas Temperature Maintained at an Average Value Approximating 300°F.



(d)-Low Burning Rate. Dampers Closed Throughout the Two Tests Except for a Short Period at Beginning.

FIG. 8 (CONCLUDED). GRAPHICAL LOGS SHOWING DATA TAKEN DURING SPECIAL TEST OF SECOND DESIGN taken while the fuel was burned at a moderately high rate approximating 6 lb per hr. During the 12-hr period of this test the dampers were closed when the temperature of the flue gases exceeded 550 deg F and were opened when this temperature was reduced to 350 deg F. The graph of the flue gas temperature indicates that the fire responded readily to a change in the position of the dampers at all times throughout the period. The graph showing the percentage of CO_2 in the flue gases indicates that there is considerable variation in this performance item when the position of the dampers is frequently changed. The average percentage of CO_2 for this test period was approximately 9.0 percent.

Graphs that indicate the results obtained from a 24-hr period in which the fuel was burned at a medium rate approximating 3½ lb per hr are shown in Fig. 8c. During this period an attempt was made to keep the temperature of the flue gas constant at 300 deg F. During the fore part of the period, when the fire was most responsive, the dampers were closed nearly all the time; near the end of the period, when the fire was not very responsive, the dampers were open continuously. These data indicate that satisfactory heating performance may be achieved with a handfired furnace of this type by giving it attention only once each 24 hr during mild weather and during moderately cold weather. However, the low percentage of CO_2 during the last half of the period indicates that better combustion efficiency would have been achieved if the furnace had been refired after 12 hr of operation.

Figure 8d shows two sets of graphical logs, each covering a 24-hr test in which the fuel was burned at a very low combustion rate except for a brief period after firing the furnace. The graphs, which are shown as solid lines, are for the same test that is covered by the smoke record in the lower left-hand portion of Fig. 6. The broken lines are graphs showing draft, flue gas temperature, percent CO_2, and smoke density for the same test period that is covered by the smoke record in the lower right-hand portion of Fig. 6.

This second test under hold-fire conditions was conducted as an afterthought. Approximately 20 hr elapsed between the end of the smoke record shown in the lower left-hand portion of Fig. 6 and the beginning of the smoke record shown in the lower right-hand portion of the same figure. It was the original intention to end the test at the close of the first-mentioned record, but when it was observed on the following morning that the fuel bed condition differed from that which occurred at either of the two previous firings it was decided to reactivate the test and continue it for another 24 hr. At point A on the lower left-hand record the small bed of coke from the previous charge was well ignited, at point B near the end of the same record the fuel was nearly "dead" and a portion of it still contained its original volatile matter, whereas at point A of the lower right-hand record the fuel was again nearly dead but contained no volatile matter.

No data were taken for the intervening cycle except for the record of the smoke produced when the technique of firing consisted of pushing back a small bed of nearly dead and only partly coked fuel and placing a small charge of fresh coal without waiting for the fuel previously in the furnace to become ignited. The record of the smoke resulting from this operation followed by the closing of the dampers after the flue gas temperature had reached 400 deg F is shown at points B and C respectively on the smoke record in the lower left-hand portion of the figure.

The principal difference between the two test conditions shown by the two sets of graphs in Fig. 8d was in the temperature of the small bed of coke in the furnace when it was fired. At the time of firing in the cycle represented by the graphs which are shown as solid lines, the small bed of coke was red-hot when the furnace was fired, whereas at the corresponding time in the cycle represented by the broken lines the small bed of coke was almost completely "dead," with only a few glowing coals in the interior of the fuel bed.

In the case of the first-mentioned cycle, the fire responded almost instantly and the flue gas temperature reached a value of 400 deg F within 15 min after the furnace was fired. In the case of the second cycle, approximately the same volume of coke remained in the fuel bed but it had cooled to the point where only a small portion was still ignited when the furnace was fired. This condition was due to the fact that the dampers had been continuously closed for a period of 18 hr. It may be noted that the temperature of the flue gases at the time of firing was only 104 deg F. In the second test the fire responded much more slowly after firing and the dampers remained open for nearly 2 hr before the temperature of the flue gas reached 400 deg F.

The conditions of operation during the two periods for which data are shown in Fig. 8d were designed to simulate actual service conditions during early fall and again in late spring. At those times during each year the heating plant is called upon to deliver heat for a few hours in the morning, but more than a very small heat output at any other time causes serious discomfort from overheating. These are the conditions under which it is most difficult to achieve satisfactory results from a furnace burning solid fuel. If the combustion rate is too low during a long period of hold-fire, ignition is lost in all parts of the fuel bed, and the fire must be rekindled. If the combustion rate during hold-fire operation is too high, overheating will occur in the spaces served by the plant. The data shown in graphical form by the solid lines indicate that a handfired furnace of the type tested will respond quickly after firing even when only a small amount of coke remains from the previous charge, providing that the dampers have been open for an hour or more prior to firing so that the coke is well ignited. In actual service under thermostatic control, there is usually some demand for heat a few hours before the hour at which the average householder would find it convenient to fire the furnace. Consequently, the coke from the previous charge would usually be well ignited when the furnace is fired, even in early fall or late spring when the weather is so mild that heat loss from the house is negligible or indeed negative throughout the greater portion of the day time. In the unusual event that there had been no demand for heat prior to the time of firing, the condition of the fuel bed and the results obtained would approximate those shown by the graphs drawn in broken lines. However, the slow response of the fire would not result in discomfort in the house because the fact that the thermostat had not demanded heat indicates that the house temperature did not decrease below the comfort range during the night.

A study of the data shown in Fig. 8d reveals the fact that the draft and percent CO_2 stabilized at 0.01 in. of water and 1.0 percent respectively, approximately 6 hr after the dampers were closed, under the conditions of operation that were used in these two tests. Assuming that all the air entering the furnace passes through the 1-in.-diam bleed hole in the secondary and undergrate air damper, the rate at which fuel is burned during this condition of operation may be calculated, inasmuch as the weight of air entering the furnace is determined by the draft measured in the air tube and the weight of air passing through the furnace per pound of fuel burned may be computed from an analysis of the flue gases. A computation of the combustion rate during the condition of operation which prevailed during the latter part of the long hold-fire periods indicates that ignition can be maintained for several hours in the interior of the fuel bed while the fuel is being consumed at a rate which is less than 0.1 lb per hr. Extremely low combustion efficiency is not a disadvantage during a long hold-fire period at a time when there is no heat loss from the spaces served by the heating plant. The only significant performance item is the weight of fuel which must be burned in order to maintain ignition in the fuel bed.

The graphs indicating smoke density which appear on each of the 4 sections of Fig. 8 have been transferred from the records of Fig. 6. The values plotted in Fig. 8 are net values and show a lesser density in each case than that indicated for the same time interval on any of the records of Fig. 6, because the zero reading of the smoke recorder has been subtracted. It may be noted that the net smoke density exceeded 23 percent (No. 1 Ringleman) only one time during the entire series of tests.

Effective Thermostatic Control of the Smokeless Furnace

Figure 9 is a photographic reproduction of an actual, week-long temperature record. The chart shown was taken with the recorder placed at the 30-in. level in the dining room of the writer's home, which is an 8-room frame structure having a calculated heat loss of

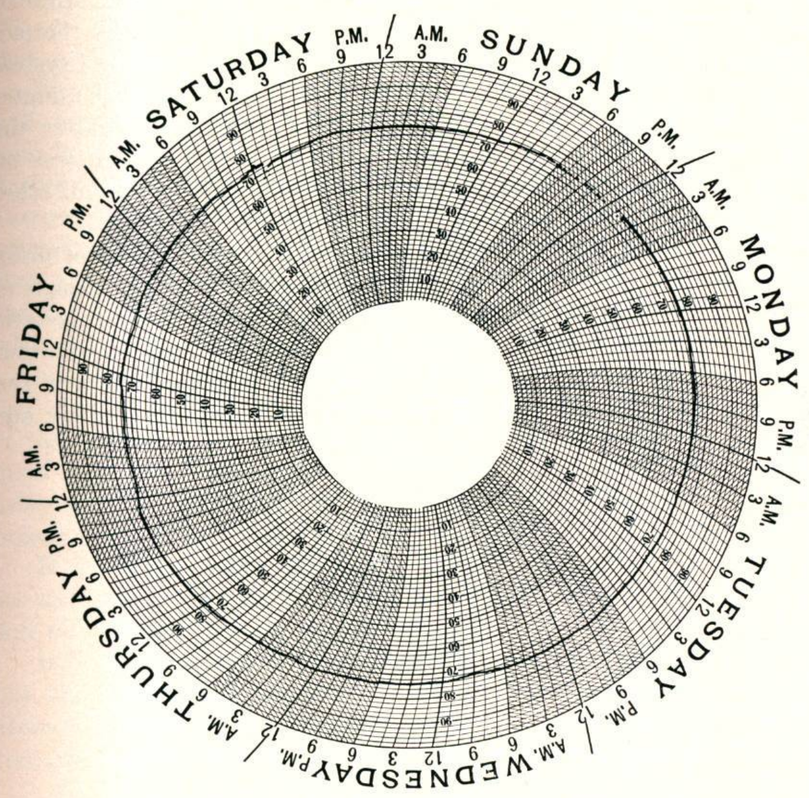


FIG. 9. PHOTOGRAPHIC REPRODUCTION OF A WEEK-LONG TEMPERATURE RECORD

70,000 Btu per hr based on an 80-deg temperature differential (basement excluded). The house is heated with a 27-in.-diam smokeless furnace, identical except for size with the unit which was used in the aforementioned tests. The temperature record shown was started at noon on Saturday, January 10, 1948, and was continued throughout the following week. The outdoor temperature varied between a high reading of +40 deg F at 2:00 p.m. on January 12 and a low reading of −3 deg F at 7:00 a.m. on January 16. The average outdoor temperature for the week was 18.7 deg F. During the week for which the record was made the furnace was fired each morning and again each evening, with bituminous coal from Franklin County, Illinois. The preparation used is known as 2 in. by 3 in. nut. At each firing the grates were shaken, the fuel bed was leveled, and the coking chamber was filled with fresh fuel. No attention whatsoever was given to the furnace between firings, which occurred at approximately 12-hr intervals. Immediately before each firing the thermostat setting was advanced several degrees to cause the control system to open the dampers and hold them open during the few minutes that were required to service the furnace. Immediately after the completion of the firing procedure, the thermostat setting was on every occasion returned to 74 deg F, where it remained at all other times throughout the week for which the record was made.

From the temperature record shown and the frequency of firing that was employed, it is clearly evident that the second design of the Illinois Smokeless Furnace is very well adapted to thermostatic control and that excellent results can be achieved during cold weather by properly attending the furnace in the morning and again in the evening. Similar results in milder weather can be achieved by one firing every 24 hr.

VI. MAKING IT EASIER TO USE COAL IN MORE NEW HOMES

RUDARD A. JONES*

For some time, solid-fuel producers and merchants have recognized that the supremacy of solid fuel in the home heating market was being challenged by liquid and gaseous fuels. Coal and coke are still the predominant fuels used for heating homes and will remain so for some time — the 1940 census shows that over four-fifths of the houses in this area, the East North Central states, are heated with coal and coke. However, fuel choices for new homes do not follow this same ratio. A 1946 report of the National Housing Administration covering 629,000 authorizations for veterans' homes shows only slightly more than half of the homes in this area will be heated with solid fuel. What are the reasons for this trend? We know that the cost and the supply of solid fuel are factors in its favor. Why, then, are more people selecting gas and oil for heating in their homes?

Two of the factors which are mentioned most often in selecting fuels are "convenience" and "cleanliness." Over a period of years solid fuel has received many a black eye on these two counts. Producers of coal and coke feel that in most cases the black eye was charged to solid fuel unjustly. Actually, the fault lay elsewhere than with the fuel itself. When the home owner comes home to find his lawn cut up because of fuel delivery to a bin on the wrong side of the house, it's solid fuel that gets the black eye. The home owner who nails a few boards in the corner of the basement and calls it a bin blames solid fuel when the basement gets dirty during the delivery of the fuel. The man who carries fuel from a bin in one corner of the basement to a heating unit on the opposite side of the basement says coal is inconvenient. When the house is so arranged that ashes must be carried across the kitchen before they can be placed outside, it is the fuel that gets the reputation of being dirty.

Every one of these difficulties is due to lack of proper provision for solid fuel, rather than to the fuel itself. In other words, the house was not planned for the use of solid fuel.

In 1946, Bituminous Coal Research, Inc., the research agency of the bituminous coal industry, made arrangements with the Small Homes Council of the University of Illinois for a study of the architectural aspects of solid-fuel utilization in homes. The work was to

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be conducted by the Department of Architecture. In 1947, the Anthracite Institute and the American Coke and Coal Chemicals Institute joined in the sponsorship. I should add that the Fuel Merchants Associations of Chicago and Illinois had been very active in promoting this idea with Bituminous Coal Research. The purpose of the program is described in the contract as "applied research in architectural design to develop house plans and other information which will promote maximum satisfaction with solid fuels for residential heating." The program has been under way now for two years, and I am just beginning to scratch the surface of the interrelated problems. We found early in the work that it is not enough to talk of planning basements — it is necessary to start with the house and lot and consider the problem as a whole.

The problem breaks down into four parts: 1) delivering the coal or coke to the house; 2) storing the fuel; 3) firing and burning the fuel; 4) removing the products of combustion.

As an initial step, it was necessary to investigate present delivery practices and study the design of lots and houses with respect to the methods now used. Fuel merchants expressed the conviction that it was desirable to eliminate completely the "bag and carry" delivery; it was also thought desirable to eliminate wheelbarrow deliveries wherever possible. The ideal delivery, obviously, is direct truck-to-bin. The first principle which was set up, then, was to design homes so that direct truck-to-bin delivery was possible. After consultation with fuel merchants and representatives of fuel merchants' organizations throughout the country, I established some further principles which seemed to outline the qualifications for the ideal bin, from the viewpoint of both the fuel merchant and the home owner. Fundamentally, it seems desirable that the fuel bin should be so placed and designed that it may be filled and trimmed from the outside without the fuel deliveryman ever entering the house or basement. Secondly, ideally the home owner should never have to enter the fuel bin in order to obtain fuel. Bins should be so designed that fuel will flow automatically to a bin outlet box in the case of handfiring, or to the feed worm in the case of binfeed stoker. Thirdly, the bin should if possible be large enough to hold a full season's supply of fuel. Finally, the bin should be dust-tight, and easy and economical to construct. Fortunately, considerable work on fuel bins had been done by the Anthracite Industries several years ago. On the basis of this work and the requirements which I outlined, several bin designs were made.

Slide 1 shows a plan of a typical bin for handfiring. Two of the bin walls are the outside walls of the basement. The bin is 8 ft square, to make maximum use of the plywood sheets forming the walls and ceiling. The left-hand wall faces the heating unit.

There are four bin outlet boxes or shovel boxes on the face of this wall of the bin. A sloping bottom, shown on the plan, is built in the bin to force the fuel to flow to the shovel boxes. The entire amount of fuel stored in the bin can be obtained through these shovel boxes without the need of anyone's entering the bin.

It is often recommended that the wooden sloping bottom be omitted so that the fuel itself may form the sloping bottom. This of course is a cheaper method, and the bin will hold more fuel. However, in this case, all the fuel does not flow to the shovel boxes. There is a greater possibility of difficulty with dirt and dust when the next load of fuel is delivered on top of the fuel remaining in the back of the bin.

An access door is provided on the wall. This is purely an emergency door and is not used when one is firing the furnace.

Slide 2 is a cross-section of the bin showing the construction of the shovel boxes and the sloping bottom. The surface material on the sloping bottom is ⅜-in. moistureproof plywood. Shovel boxes, built as shown, make it possible for the shovel to be extended into the bin 4 ft. The shovel can actually touch the foot of the sloping bottom. An 8-ft by 8-ft bin of this type can hold 5 tons of bituminous coal when the fuel is stored 5 ft high. All of this storage is active storage — that is, the fuel flows to the shovel boxes and can be obtained without entering the bin. Often it is convenient to make the bin only 6 ft from the front to back and to leave out the sloping bottom. This reduces the active storage capacity of the bin three-quarters of a ton.

The ceiling of the bin is lined, to prevent dust from escaping during delivery. We recommend the use of treated coal, but there is always the possibility of stirring up the fines which are already in the bin.

A bin for hand firing was built in the Small Homes Council Research Residence. Slide 3 shows it in process of construction. You are looking at the wall of the bin which faces the firing unit. The vertical framing is clearly visible; behind it is the framing for the shovel boxes. One piece of the sloping bottom has been placed in position but does not show clearly in this view.

Slide 4 shows a view from inside the bin looking toward the back of the front wall. This gives a more detailed idea of the framing for the shovel boxes.

Slide 5 shows the bin nearly completed and demonstrates how the shovel boxes are used. Upon completion, the shovel boxes will be covered with plywood doors, hinged at the top, which may be kept closed except during the periods of use.

One of the problems involved in this type of bin in the basement of a house is to provide enough room in the foundation wall for the delivery window or delivery chute. Modern architectural preference demands that the house be set low to the ground. Most houses are set so that only 8 in. of the masonry foundation wall are exposed above grade. This amount, of course, is insufficient to accommodate a fuel delivery window. Slide 6 shows a recommended grading plan. Assuming that the house is to be placed on a level lot, the driveway is built at the prevailing grade level. The first floor level of the house is then set 3 ft 4 in. above the driveway level. This allows one foot for the floor construction and 2 ft 4 in. of foundation wall above grade, which is adequate to accommodate the fuel delivery window. The sketch shows a fuel delivery window 24 in. high by 32 in. wide. Wherever possible, a window this large should be used, as it makes the delivery of fuel much easier. Actually, standard windows are slightly smaller than this dimension (about 21 in. high by 30 in. wide). There is also a still smaller window, on the order of 17 in. by 24 in. This window is, of course, acceptable, but not as desirable as the larger one. On the other side and at the rear of the house the same amount of foundation wall is exposed as shown in this illustration. When this amount of foundation is above ground, basement windows can be placed above grade, eliminating the need for areaways and thus cutting down the construction costs of the house.

At the front of the house, the excavated material from the basement is built up so that the foundation wall is covered as much as possible. At the lefthand side of the slide you can see that only 8 in. of foundation wall are exposed and the house appears to be quite low to the ground, in accordance with today's desirable architectural appearance.

I have a few pictures showing actual delivery into a bin, to give you an idea how this works out.

First a slide showing the appearance of the house from the street. At the time this picture was taken the house was still under construction; the grading and landscaping had not been completed. However, you can notice the difference in the grade level at the driveway side of the house and the front.

Slide 8, a view taken from the front of the house at the edge of the driveway, shows a motor conveyor in position for delivery.

The next slide shows a clearer view of the delivery with the conveyor. Notice that the large fuel delivery opening gives adequate space for handling the conveyor.

I prefer the motor conveyor as a method of placing fuel in the bin. Fuel can be placed farther in the bin, with less effort, by this method than by any other method that I know.

Of course, a metal chute used with a high-lift truck as shown on Slide 10 is also suitable for rapid, direct truck-to-bin deliveries.

Now I should like to show you a few slides of houses which we have designed in order to illustrate solutions for various problems that occur frequently in designing for solid fuel utilization. I will try to explain the particular features of each house that are of interest. I will mention the four basic problems outlined previously — delivery, solid fuel storage arrangements, firing and burning of the fuel, and removal of the products of combustion.

Slide 11 shows a small home, about the size of many homes being built by speculative builders today. The accommodations are about equal to homes that are offered for sale in many areas. The house has two bedrooms, a living-dining area, a kitchen, and a bath. I believe this house is a little better than the run-of-the-mill minimum house because an entry and central hall make it possible to go to any room in the house without passing through the living room. The kitchen and bathroom are side by side, so that only a single plumbing stack is required. As for the solid fuel features, the chimney has been placed at the center of the house, where a maximum regain of heat can be had. Notice particularly the arrangement of the basement stairs. In small homes of this type it is often convenient to combine the service entrance of the house with the basement stairs, as has been done in this case. Four risers down from the first floor level of the house is a landing which leads to the service entrance door, which is at grade level. From the landing, the stairway continues on down to the basement proper. There is nothing new about this type of stairway; it was common in houses built ten or twenty years ago. The stairway does have some exceptional advantages when it comes to the utilization of solid fuel in the house. Obviously, in a small house it is not possible to provide a special basement stairway for ash removal. One stairway has to serve for several purposes. With the arrangement shown, it is possible to carry ashes out of the basement with a minimum of effort, and without tracking through any part of the living quarters.

Looking at the basement plan (Slide 12), you can see that the stairway is conveniently located with respect to the heater room.

The ash containers are taken out of the heater room and carried up only 9 steps to the service entrance. The ashes never reach the first floor level.

The ample solid fuel storage bin is about 8 ft by 8 ft; the details are similar to those I have shown, except that the emergency access door to the bin is located above one of the bin outlet boxes. We have shown a location for the heating unit and for a solid-fuel-fired water heater. There is a suggested layout for ducts for a gravity warm air system, using an extended plenum with horizontal ducts. Mr. Childs will tell you more of this type of system this afternoon. Of course, forced warm air, steam, or hot water are equally suitable for heating the house.

For ease in handling firing tools, a clearance of 6 ft has been provided between the face of the bin and the firing door of the heating unit. This seems to be about the optimum distance to suit the average person when the heater room is laid out so that a 180-deg turn must be made from the bin to the heating unit. Distances much greater than 6 ft require extra steps; shorter distances make it awkward in handling shovels and pokers.

I have shown half of the basement as unexcavated. Obviously, the entire basement can be excavated if desired.

The next slide, No. 13, is a sketch showing how this house might appear from the street. Notice how the grading scheme previously outlined has been followed. On the side of the house there is ample room for the installation of the fuel delivery window. At the same time, the house appears to hug the ground very closely from the street. The accommodations in this house are almost identical, room for room, with those in the Industry Engineered Home. In fact, this house was designed to offer the same accommodations, and at the same time provide for the utilization of solid fuel. The Industry Engineered House was not designed with solid fuel in mind.

One of the early difficulties that we found in designing homes for solid fuel utilization was to provide for a large enough bin and at the same time make the bin convenient for the home owner. I am thinking particularly of the fundamental requirement: "Build the bin so that it is not necessary to enter it to obtain fuel." In the usual basement with a 7-ft ceiling, fuel cannot be stored much higher than 5 or 5½ ft. With this limitation, and with the angle of slope at which the fuel stands, there is no value in increasing the front-to-back dimension of a bin for hand shoveling much over 9 ft; once this dimension is exceeded the additional storage gained by enlarging the bin is a dead storage—the fuel so stored will not flow to the bin outlet boxes. Even in an 8-ft by 8-ft bin without a sloping bottom, a fairly large percentage of fuel stands in the corners and is inaccessible unless the homeowner walks into the bin to shovel it over near the bin outlet boxes. This of course is not desirable; we are trying to keep the homeowner out of the bin so that he will not track coal over his basement and the rest of the house. For hand shoveling it is seldom desirable to make a bin more than 10 or 12 ft wide, as the distance between the shovel boxes and the firing door of the furnace becomes too great.

The limitations on a binfeed stoker are about the same. If the worm conveyor is in the middle of the bin, nothing is gained in extending the bin more than 5 ft on either side of the worm; that is, no additional active storage is gained by making the bin more than 10 ft wide. The best front-to-back dimension depends on the stoker worm conveyor length. Usually it is of little value to make the bin more than 2 ft longer than the worm. How, then, increase the active storage capacity of a bin? Since we gain nothing by increasing horizontal dimensions, the answer seems to be to increase the height of the bin. This principle led to the development of a design which we call the "two-story bin." It is nothing more than a bin which extends from the floor of the basement to the ceiling of the first floor. By using a motor conveyor, fuel can be placed in the bin to a level 5 ft above the outside grade line. This gives a total storage height of slightly over 11 ft. This means we have more than doubled the capacity with respect to the usual basement bin.

Slide 14 shows a house designed around the idea of the two-story bin. The living and working areas are fairly standard, with large living–dining room, convenient U-shaped kitchen, and downstairs lavatory. Upstairs are two bedrooms and a bath.

The two-story bin is in the lower lefthand corner of the slide. Notice that it is adjacent to the driveway so that direct truck-to-bin delivery can be made with the use of a conveyor.

Another special feature is the provision for two basement stairways. Obviously, this is a more expensive arrangement than in the minimum house shown you previously, but it does have advantages. This is the type of outside service basement stairs which we like to recommend. The stairway is located in the breezeway between the garage and the house proper and is therefore covered and almost completely enclosed. This eliminates the problem of removing snow, ice, leaves, and so forth. At the same time, the stairway is open directly to the outside and is therefore readily available to service men.

Looking at the basement plan, you can see that this service stairway terminates in a hall in the basement just outside the heater room (Slide 15). The owner of this house can employ an ash-removal service man who will go to the basement and remove ashes from the heater room and carry them outside. The door to the laundry and the door to the rest of the basement can be locked so that the heater room and service stairs may be isolated from the rest of the basement and house. Incidently, this service stairway is also convenient for carrying laundry to the backyard.

The second basement stairway is an inside stairway that will be used by the homeowner for access to the heater room when he checks the operation of the heating equipment. It is also the route to the recreation room and laundry room in the basement.

In this house the lower portion of the two-story bin (the part in the basement) is slightly larger than the first-floor portion, to accommodate a longer stoker worm. This illustrates the flexibility which can be obtained in designing this type of bin.

To give you a better idea of the appearance and function of the two-story bin we have constructed a scale model of such a bin (Slide 16). It was not constructed for this particular house, but the conditions were very similar. First is a view of the corner of a house as it would be seen from the driveway. The fuel delivery opening for this type of bin is an ordinary door. Behind the door are removable slats which retain the fuel.

We prefer this type of opening to the standard cast iron chute for several reasons. First, by opening the door and removing the slats the fuel can be delivered at a low level in the early stages so that the fuel will not fall too far and be broken up during delivery. As the pile builds up in the bin, the slats may be added and the motor conveyor may be elevated until the final level of the fuel is reached. Secondly, we believe this type of opening to be superior to the standard fuel delivery chute in that it will prevent the marring and dirtying of the wall of the house. If an ordinary fuel delivery window of malleable iron or pressed steel type were placed on the wall at the proper height (the sill about 5 feet above the outside grade level), any fuel which fell from the conveyor would have a tendency to mar the wall. Using the full-size door eliminates this problem, as the opening extends the full height. A third advantage: If necessary, it is easy for the fuel deliveryman to enter the bin through this type of opening.

Slide 17 shows a section down through the two-story bin. Note that the bin extends the full height of two stories — the basement and the first story. In this bin we have shown the worm for a bin-feed stoker, and also a shovel box, so that coal might be obtained for a domestic hot water heater. I would like to repeat some of the advantages of this type of bin: No special grading is required to provide for a fuel delivery opening. The fuel is stored to a depth of 11 or 11½ ft. There is little dead storage. Only a small area of the first floor is occupied by the bin. This area can be made even smaller, and at the same time the bin may be enlarged in the basement. The construction of the bin is simple. For this house the bin has been so placed that it parallels the joists, and no particular problems of construction are involved.

As yet we have not constructed an actual bin of this type, but from our experience with other bins we feel certain that there would be no serious difficulty. We hope to build one in the near future.

This house (Slide 18) illustrates a still different type of bin. There is nothing particularly unusual about the general house plan — a large living–dining area opens out to the terrace, which should preferably be on the south of the house. Two bedrooms are ample in size and are convenient to the bath. Once again, two basement stairways are provided. The outside service stairway is covered by the breezeway similar to the one in the house before, while the inside stairway is accessible from the hall and serves as an access to the recreation and laundry rooms in the basement.

The bin for this house is built under the concrete slab of the breezeway, and the fuel delivery opening is in the top of the bin. Delivery to the bin would have to be made by chute or conveyor from a truck on the driveway. If a bin of this type can be built under the driveway, delivery can be made by dumping directly from the truck. The construction of this sort of a bin is more expensive than the bins we have outlined previously. One difficulty that may be encountered with the use of this type of bin is the possibility of the fuel freezing in extremely cold weather, since the bin is almost completely isolated from the rest of the house. Freezing difficulties are especially probable in those areas where it is still the habit to wet down fuel during delivery.

Another problem with a bin of this type—since the fuel delivery opening is a manhole in the top of the bin, it is more difficult to trim the bin. A motor conveyor cannot extend into the bin; it may only serve to transfer the fuel from the truck to the opening. One possible correction for this trimming difficulty would be the installation of larger openings or even of multiple openings to the bin.

Looking at the basement plan, we see in Slide 19 that two bins have been provided. One bin is for stoker-size fuel; the second for a slightly larger fuel for the handfired hot water heater. Of course, if a boiler system is used the boiler may be operated the year 'round and domestic hot water obtained from an indirect heater connected to the boiler. Once again, notice that it is possible to lock the door of the laundry and the door of the heater room so that the heater room and service stairs may be isolated from the rest of the basement.

Another type of small home (Slide 20) which has become increasingly popular in the past few years is the basementless house built on a concrete slab. It is perfectly feasible to design a home of this type so that solid fuel may be utilized with a maximum of convenience.

This house follows the general pattern of the houses previously shown, in that it is a two-bedroom home with a combined living–dining room. Of course, in building basementless homes the space lost by the omission of the basement must be provided somewhere on the first floor. In this plan, the house has been extended at one side to form space for a fuel storage bin, for a heater room, and for a utility room which replaces the basement laundry. The heater room and the fuel storage bin are at the same level as the rest of the house. In another version, these rooms may be placed slightly below grade—that is, down to the footing level. This gives a little more height in the fuel bin at little additional cost, as it is necessary to excavate for the footings in any case. Where the bin is aboveground (as shown in this plan), either a standard fuel delivery window or the full-length door as described in the account of the two-story bin may be used as the fuel delivery opening. If the standard window is chosen, the sill of the window should not be higher than 5 ft above the driveway at the point of delivery. To deliver fuel to bins above ground level, either a motor conveyor must be used, or the fuel must be shoveled directly from the truck to the bin. Obviously, this type of bin is not suitable for bag-and-carry or wheelbarrow delivery. Once again, the bin has been placed adjacent to the drive to make direct truck-to-bin delivery easy.

Both a heating unit and a separate hot water heater are shown in the heater room. The heater room is laid out on the assumption that the units would be handfired. A clearance of 6 ft has been left between the face of the heating unit and the bin. Arrangements for stoker firing can be made readily.

There are several possible ash-removal methods. Ash containers may be set out along the driveway from the heater room. Another possibility is the installation of a gravity ash-removal pit beneath the heating unit. This ash-removal pit could be of the large type which would hold an entire season's accumulation of ashes, or it might be of a smaller type which could contain only a bushel basket-sized container. Either pit may be designed so that the removal of the ashes is accomplished from the outside of the house, thus relieving the homeowner from any possibility of dust in connection with the handling of ashes.

Slide 21 shows a sketch of how this house might look.

The next series of slides shows the plans and sketches for a split-level house — a type which seems to be increasing in popularity. I believe that I can show you that this particular house has some distinct advantages when it comes to the utilization of solid fuel. Basically, the split-level house is a home in which the living area is placed at or near the grade of the yard, and the sleeping area is a half-flight of stairs above the living room. The partial basement is below the sleeping area.

Slide 22 shows the general layout of the living and sleeping levels. The front entrance to the house opens into a hall which leads to every room of the house. The wall facing the garden has a considerable portion of glass so that the garden may be enjoyed from the living room. A flight of six or seven steps leads up to the bedroom level, where there are two bedrooms and a bath. Another half flight of stairs leads down to the basement.

Slide 23 is a plan of the partial basement located under the bedroom wing of the house.

In a split-level house, the basement is only 6 steps down from the first floor, as compared to 13 steps for the usual house. This arrangement means that the basement walls actually extend 4 ft above the outside ground level. No special grading is needed to accommodate the fuel delivery window. Also, standard-size windows may be used in the laundry-recreation space in the basement, making this area extremely light and pleasant.

Once again, the fuel bin has been placed adjacent to the driveway to facilitate direct truck-to-bin fuel delivery. The layout of the heater room shows an arrangement for a binfeed stoker connected to a boiler. A furnace may be used if desired. Notice that the stoker enters the side of the boiler in order that the space in front of the firing door may not be obstructed. For handling clinker tongs, a clearance of 6 ft is provided in front of the heating unit.

One unusual feature of this house is the method of removing ashes. The house has been provided with a device which we have called the ash-setout areaway, whose location is shown on the plan marked "A."

Slide 24 shows a sectional view of an ash-setout areaway, looked at from the outside, for any house — not this house in particular. The areaway is nothing more or less than a concrete box with a lid, placed at the outside of the house adjacent to the heater room. This box has an opening to the heater room. Filled ash containers are placed in the box from inside the basement. The ash-removal service man removes the containers without entering the house. One advantage of the ash-setout areaway is that ashes need not be carried out of the house. The homeowner may place ash containers in the areaway from the heater room, and then forget them, except that if ashes must be placed at the curb, the containers must be handled again.

For the split-level house, the floor of the ash-setout areaway is only 12–16 in. above the basement floor. In the usual house, when the basement floor is farther below grade level it is necessary to build the ash-setout areaway higher. In most cases the areaway may be so designed that it is not necessary to lift the ashes more than 30 in. We have not as yet actually built a covered ash-setout areaway of the design shown, but we have built an open ash-setout areaway in a house with an ordinary basement.

Slide 25 shows a view of an open ash-setout areaway from inside the basement. The homeowner is placing the ashes out the window into the open ash-setout areaway. In this particular basement two steps are needed to reduce the lift to the recommended 30 in. This sort of design is practical in all basements where the foundation wall is exposed sufficiently to accommodate the fuel delivery window. In the split-level house which we have just seen, the steps are not necessary. In the covered ash-setout areaway, the window is replaced with a small plywood door. We much prefer the covered design, as it eliminates difficulty with leaves and snow. The man who used this experimental areaway last winter found it very satisfactory and used it in preference to an open outside basement stairway, which he also had available.

Slide 26 is a view of the split-level house from the garden side, with the kitchen in the immediate foreground. Notice the position of the ash-setout areaway and the fuel delivery window. The living level of the house is 8 in. above grade level. The sleeping level is half a flight above the living level.

Another architectural problem which is often ignored but does exist is the planning of the stove-heated home. The 1940 census shows that over half the houses of the United States are heated only by stoves or some other form of space heater. Actually, in this area few homes are being built which will be heated by stoves, but in the southern states there is a considerable market for this type of house.

In this plan (Slide 27) we have attempted to design a compact home which could be readily heated by a single heater. We have tried to locate the heater as centrally as possible and at the same time provide a direct route for the carrying of fuel and the removing of ashes. Moreover, we have so placed the flue that a domestic hot water heater and a solid fuel-fired kitchen range can be connected to the chimney. The units are so placed that heat can be readily circulated through the house and yet they do not cut the space in the living room. Fuel storage is provided in a small bin on the back porch. The fuel may be carried through one end of the kitchen to the stove at the center of the house. The "L" on the plan at this end of the kitchen indicates an area assigned to the laundry facilities of the home — an area backed up against the bathroom to limit the amount of plumbing necessary.

With these slides I have attempted to show that it is possible to design convenient and pleasant homes which can utilize the economical heat of solid fuel to the best advantage. As I pointed out earlier, we soon found out that it was necessary to consider the whole house and lot in doing this work. It is not sufficient to plan a convenient basement. Too often, the fuel cannot be delivered to this basement or the ashes removed from it. The house must be designed with these features in mind from the very beginning.

The Small Homes Council will soon issue a bulletin which is tentatively titled "Homes Planned for Coal or Coke," prepared by this project to show how solid fuel may be used in houses with maximum satisfaction. Four house plans will demonstrate the ideas. Other pages in the bulletin will give instructions for the proper building of bins and for convenient ash-removal. The bulletin will be distributed to the mailing list of the Small Homes Council and will also be available for purchase in quantity lots by those interested. I hope that it will serve to prove to the general public that it is easy and convenient and economical to use solid fuel for the heating of small homes.

VII. GRAVITY WARM-AIR SYSTEM USING HORIZONTAL DUCTS

ROBERT W. ROOSE,* MORRIS E. CHILDS,*
AND KENNETH L. LAMM†

I. INTRODUCTION

A gravity warm-air heating system is in many respects an ideal heating system for the small, compact home. However, as installed in accordance with present-day practice it obstructs headroom in the basement. If a properly designed gravity warm-air system can be so installed as to give full headroom in all parts of the basement, the major objection to this system can be eliminated. In a system which provides ample headroom the heated air would be carried vertically, or nearly so, from the heating surface to within a few inches of the floor joists, and then horizontally to the stacks which lead to the registers. It was found in tests conducted in the University of Illinois Mechanical Engineering Laboratory that such a system would perform as well as the conventional gravity warm-air heating system.[1]

Opportunity to study such a system in a residence arose in the fall of 1947 when a 4½-room Industry Engineered Home was constructed on the Small Homes Council Plot at the University, in Champaign.

II. SMALL HOMES COUNCIL RESEARCH RESIDENCE

The Small Homes Council Research Residence is a one-story structure of standard frame construction with a full basement, typical of the small well-built American home of today. The front or south view is shown in Fig. 1.

The exposed wall consists of ⅛-in. pressed asbestos mill board on the exterior, standard building paper, 1-in. wood sheathing on 2-in. by 4-in. studs, 3⅝-in. mineral wool blanket insulation with vapor barrier attached, and ½-in. gypsum board on the interior. The calculated coefficient of heat transmission, U, for this wall section is 0.076 Btu per hr per sq ft per deg F temperature difference. Storm doors were used on all three outside doors. All except one of the windows on the first floor were weatherstripped, and this was the only one fitted with storm sash. The heat losses from the structure

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[1] Results of those tests are presented in Bulletin 141 and Circular 45 of the University of Illinois Engineering Experiment Station.

FIG. 1. SMALL HOMES COUNCIL RESEARCH RESIDENCE

were calculated by the methods given in Manual No. 3 of the National Warm Air Heating and Air Conditioning Association, which utilizes the coefficients given in the 1947 issue of the ASHVE Guide. The infiltration loss was based upon a 15 mi per hr wind velocity and the lineal feet of crack existing around the doors and windows, as recommended in the Guide. Only the first story, which consisted of 5516 cu ft, was heated during these tests. The floor area of the first story was 690 sq ft and the ceiling height 8 ft, while the floor area of the basement was 681 sq ft and the ceiling height 7 ft 10 in. to the bottom of the floor joists. The calculated heat loss for the first story was 37,124 Btu per hr, based upon design temperatures of −10 deg F outdoors and 70 deg F indoors.

Standard construction was used throughout. The floor was hardwood, laid on wood subflooring, which was on 2-in. by 10-in. joists. A 3-in. thickness of mineral wool, batt-type insulation was laid on the attic surface of the ½-in. gypsum board ceiling. The attic was vented to the outside from the east and west.

The residence was occupied by two adults and one child. Thus all tests were conducted under actual living conditions, with heat from cooking, washing, and bathing contributing to the heat supplied by the heating plant.

III. HEATING SYSTEM

Furnace

The coal-fired gravity furnace used with the heating system was the latest model of the Illinois Smokeless Furnace, developed by Professor J. R. Fellows of the Department of Mechanical Engineering

FIG. 2. THE ILLINOIS SMOKELESS FURNACE USED WITH THE HEATING SYSTEM

of the University of Illinois. The furnace, shown in Fig. 2, had a grate area of approximately 350 sq in. and a rated bonnet capacity of 55,000 Btu per hr. It was located near the center of the basement, close to the inside chimney.

Duct System

A plan of the extended plenum duct system is shown in Fig. 3. The furnace bonnet, which was 24 in. by 24 in. at the bottom, extended upward from the furnace casing to within 3 in. of the floor joists. These joists were protected by a radiation shield, which was placed inside the bonnet just below the upper surface. The tops of the warm-air trunks were at the same level as the top of the bonnet, 3 in. from the bottom of the joists. The two trunk ducts, or extended plenums, led from the furnace toward the east and west ends of the basement. With the exception of one rectangular branch which was connected to the plenum by means of a top takeoff fitting, and installed in the joist space, all branches were round and were connected to the sides of the trunks. All ducts were leveled with a spirit level.

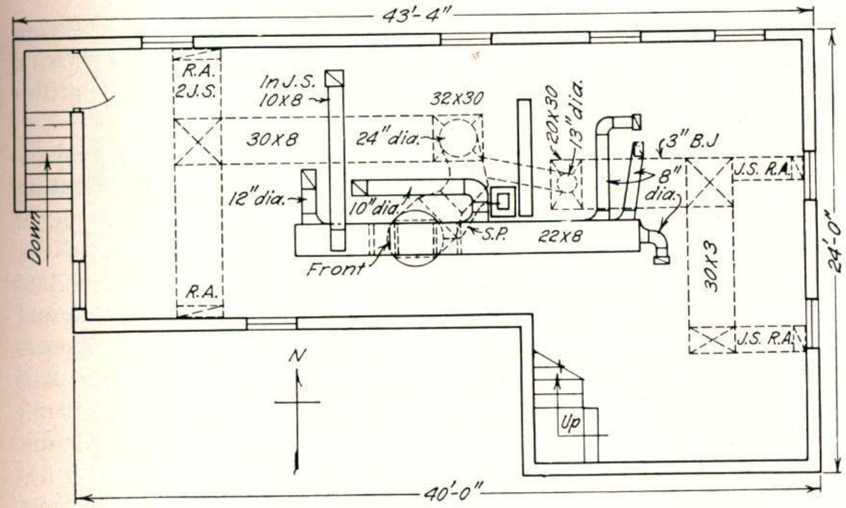

FIG. 3. PLAN OF THE EXTENDED PLENUM DUCT SYSTEM

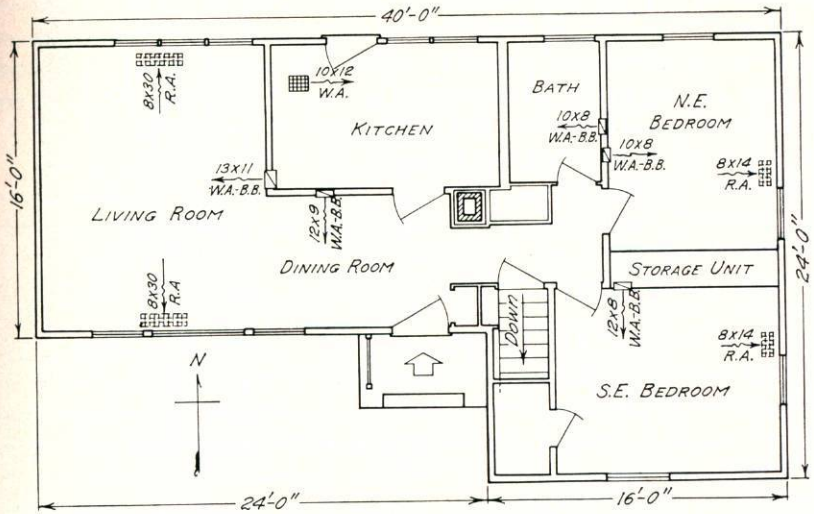

FIG. 4. FIRST-FLOOR PLAN OF SMALL HOMES COUNCIL RESEARCH RESIDENCE

Except for one floor register in the kitchen, baseboard registers were used throughout the residence. Fig. 4 shows the first-floor plan, with the arrangement of rooms and register locations. All return-air grilles were located in the floor near the outside walls.

The system was designed in accordance with the design and installation manuals published by the National Warm Air Heating and Air Conditioning Association. The registers and branch ducts were sized in accordance with Manual No. 5, and the size of the trunk ducts or extended plenums was determined by a method of addition to the trunk duct width similar to that used in Manual No. 7. Starting with a trunk of standard 8-in. depth and of sufficient width to have the same carrying capacity as the last branch, and then proceeding toward the furnace, increases were made in the trunk width for each succeeding branch until all branches on that trunk had been considered and the width of trunk required had been determined. This procedure was followed for each trunk, and the largest size so determined was selected as the standard size of main trunks or extended plenums for the system. Return-air grilles and ducts were sized according to the methods outlined in Manual No. 5.

The indirect approach of the branch to the dining room register (see Fig. 3) was necessary in order to comply with the National Board of Fire Underwriters, which states that the heated air must travel at least 6 ft from the primary heating surface to the stack boot.

Auxiliary Equipment

The room thermostat was of the heat-anticipating type and controlled the operation of the primary and secondary dampers of the furnace. It was located on the east wall of the living room at an elevation of 4 ft from the floor. A limit switch was included in the damper circuit so that the dampers would close when the air temperature in the furnace bonnet exceeded the predetermined setting of the limit switch. A barometric regulating damper on the flue pipe was so set as to limit the draft at the smoke collar of the furnace to 0.06 in. of water.

IV. Test Procedure and Instrumentation

Since the home was not constructed primarily as a heating residence the instrumentation was limited. Observations were made at the convenience of the family occupying the residence.

Thermometers were used to measure the air temperature at various levels near the center of each room. For this purpose four thermometers were attached to a standard, at levels of 4 in., 30 in., and 60 in. above the floor and 4 in. below the ceiling. Daily readings were made of these air temperatures in the living room, dining room, and the two bedrooms. A continuous record of the air temperature 4 in. above the floor in the living room was made by means of a 24-hr relative humidity–temperature recorder.

Recording instruments provided continuous records of the flue gas temperature at the smoke collar and of the bonnet temperature. The gas-filled bulb for recording bonnet air temperature was placed in the east trunk and just outside the opening into the bonnet, so that it was out of the line of direct radiation from the heating surface.

The CO_2 content of the flue gas was checked frequently by means of a portable CO_2 analyzer. An inclined draft gage was used to indicate the draft at the smoke collar of the furnace.

Daily weight measurements were made of the coal fired into the furnace. An Illinois (Saline County) coal having a calorific value of 12,545 Btu per lb (as received) was used throughout the heating season.

The quantity of air circulated in the system was determined by means of a vane-type anemometer installed in the return-air duct near the furnace.

Register air velocities were measured by means of a velometer.

Observations of the wind velocity, wind direction, intensity of solar radiation, and outdoor temperature were made at a weather station located about 50 ft southwest of the residence.

V. Temperatures and Relative Humidities Maintained

Preliminary Statement

The main purpose in a field investigation of this type is to ascertain the comfort which can be obtained and to study the operating characteristics and economy of the heating plant.

A complete evaluation of comfort conditions in the Small Homes Council Residence was not possible, since air movement within the rooms and surface temperatures were not observed. However, since the room air temperature and relative humidity are, in general, the most important factors affecting comfort with a gravity warm-air system, a fairly complete evaluation can be made.

From the standpoint of comfort, the conditions in the living zone, from the floor to the 60-in. level above the floor, are of greatest importance. The temperatures in this zone should be kept as uniform as possible, and the temperature difference from room to room should be small.

Difference in Temperature Between Rooms

In the beginning of the test season, with all the duct dampers in the wide-open position, temperature observations made in the various rooms indicated that the system was in good balance; in other words, it was found that there was a satisfactory degree of uniformity between rooms. Although the temperature difference between rooms increased slightly with a decrease in outdoor temperature, the duct dampers were not moved from the wide-open position throughout the heating season.

The table below shows the maximum observed temperature differences between different rooms at the level of 30 in. from the floor. The maximum difference was least when the sun was not shining, and increased slightly with an increase in solar heat gain through the large glass area on the south.

	Sun	*No Sun*
Average weather (approximately 35 deg F).......	3.6	2.7
Cold weather (approximately 0 deg F)...........	4.6	3.8

The maximum temperature difference observed during periods when the sun was not shining occurred between the dining room and the south bedroom. Although this difference could have been reduced by proper damper adjustment, it was so small that no adjustment was considered necessary. When the sun was shining the maximum temperature difference was observed between the north bedroom and the dining room. This difference may be explained by the fact that solar transmission and radiation through the large glass area on the south kept the temperature at the thermostat above its setting, while the north bedroom cooled off. The addition of draw curtains on this large glass area alleviated the situation to some extent.

Temperature Difference Within Rooms

The average differences in temperature between the air at the 30-in. level and that 4 in. above the floor, 60 in. above the floor, and 4 in. below the ceiling are shown plotted against the outdoor temperature in Fig. 5. The temperature at the sitting level, 30 in. above the floor, has been used as the reference temperature in these plots. The study of air temperatures was primarily devoted to conditions obtained in the living zone, which is the zone between the breathing level at 60 in. above the floor and the floor level. The air tempera-

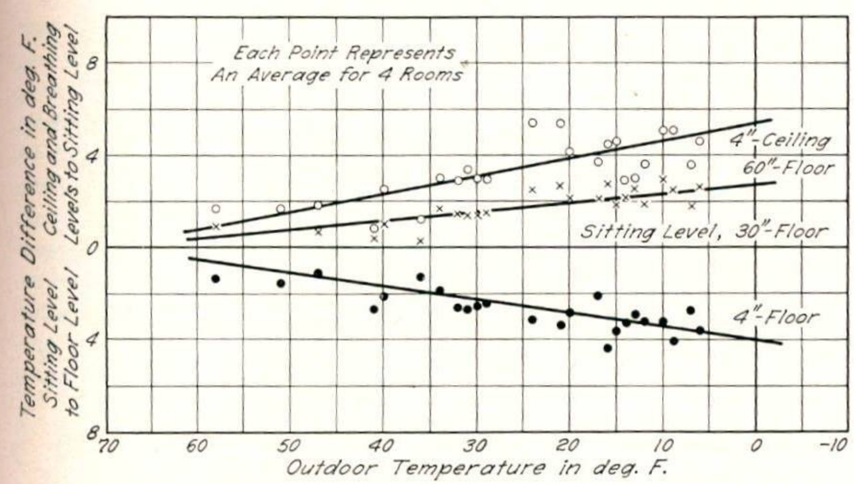

FIG. 5. AVERAGE TEMPERATURE DIFFERENTIALS EXPERIENCED IN RESIDENCE

ture at the ceiling level is of little significance in determining the condition of comfort in homes having average ceiling heights of 8 ft or greater. However, from the standpoint of maintaining a minimum amount of heat loss through the upper exposed walls and through the ceiling, a low temperature at the ceiling would be desirable.

The temperature at the thermostat, 48 in. above the floor, was maintained at 74 deg F. This setting was varied occasionally by the occupants.

In average winter weather of about 35 deg F a difference of approximately 3.2 deg F was observed between the average temperature of the air 4 in. above the floor and that 60 in. above the floor. This difference increased to 6.6 deg F during the coldest outdoor weather (about 0 deg F).

Relative Humidity

Relative humidity is another index of comfort in the home. The average daily relative humidity in the residence experienced during the days when the average outdoor temperature was below 30 deg F was usually between 25 and 30 percent. In order to maintain the relative humidity above a minimum value of 30 percent as given in the Comfort Chart on page 212 of the 1948 ASHVE Guide, additional moisture should have been added to the air when the outdoor temperature was below 30 deg F.

VI. Operating Characteristics of System

Average Daily Bonnet Temperatures

By means of a 24-hr bonnet air temperature recorder, it was possible to obtain a 24-hr average of the bonnet air temperature and to correlate the average value with the average outdoor air temperature for the day.

The average daily bonnet temperature, as shown in Fig. 6, was only 132 deg F at an outdoor temperature of 0 deg F. This low bonnet temperature is indicative of a well-designed, free-flowing gravity system. Low register air temperatures resulting from the moderate bonnet temperatures were instrumental in maintaining a small temperature difference in the living zone.

Volume and Velocity of Air Flow

In a gravity system the motive head producing flow depends upon the difference in weight between the heated air leaving the bonnet and the cooler air entering the furnace at the return shoe. That is, the volume of air circulated will increase with a rise in bonnet temperature, which in turn occurs as outdoor temperature decreases.

Periodic readings were taken of the time required for three revolutions of the anemometer as well as the bonnet temperatures. The volumes of air circulated were determined from a calibration curve showing the relationship between air volumes and time for three revolutions of the anemometer. It was then possible to plot the air quantity circulated against the bonnet temperature and arrive at the upper curve of Fig. 6, which shows the volume of air circulated during varying degrees of outdoor temperature. For example, the volume of air circulated at 0 deg F was 320 cu ft per min.

With this air flow, 19,200 cu ft per hr was returned to the furnace by way of the return-air shoe. On the assumption that only the air in open spaces of the house, 5252 cu ft, would be recirculated the equivalent recirculations were 3.65 per hr. Actually, not all the air would be passed 3.65 times per hr through the furnace, since there is a constant replacement and exchange of air due to inleakage at windows and doors. Hence, the term "equivalent recirculations" rather than "recirculations" has been used. It is this rapid turnover of the air contents of the house, combined with the infiltration of fresh air, which constitutes the ventilation effect of warm-air heating.

During a study made at a bonnet temperature of 110 deg F and an outdoor temperature of 19 deg F the register air velocity averaged 115 ft per min. The velocity at the register of the most active duct

was 132 ft per min and the lowest velocity at any register was 96 ft per min. At a bonnet temperature of 94 deg F and an outdoor temperature of 57 deg F the register air velocity averaged 71 ft per min the maximum being 103 ft per min and the minimum being 42 ft per min. The register air velocities indicated that all supply ducts were active. Furthermore, the register velocities were sufficiently low in magnitude so that no sensation of excessive air motion was experienced.

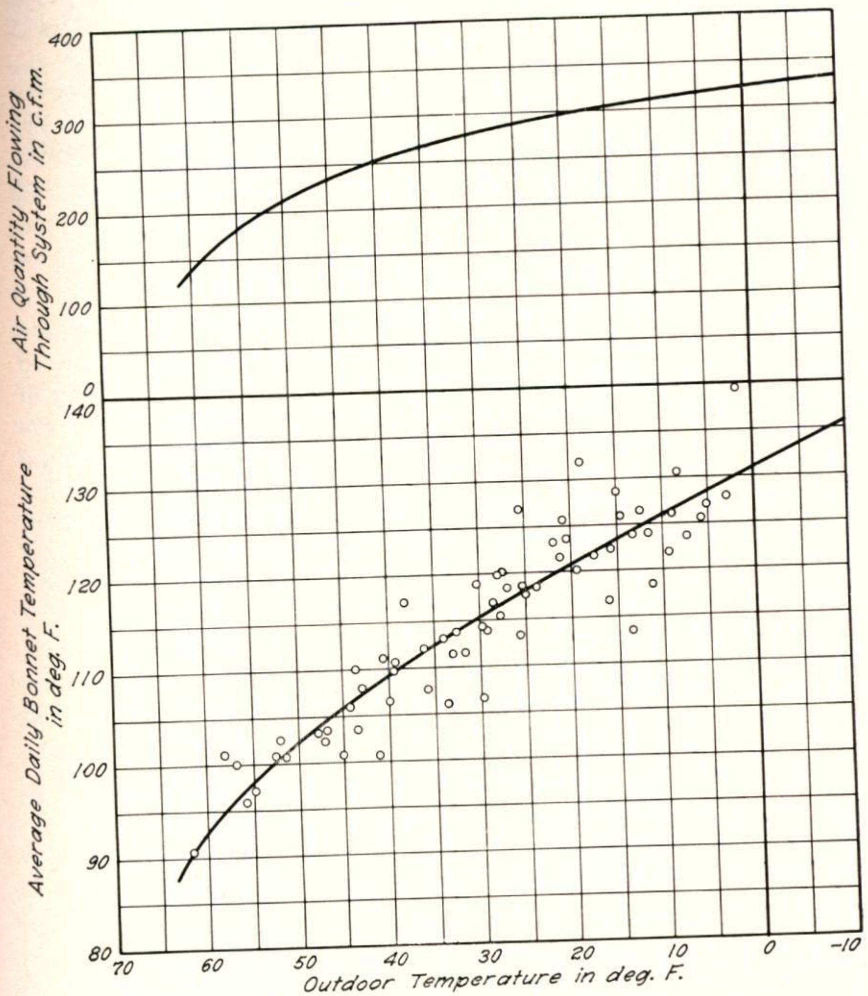

Fig. 6. Average Daily Bonnet Temperature and Average Air Delivery Experienced with System

VII. Conclusions

The results obtained from this study of a gravity warm-air extended plenum system indicated that the performance and economy of operation were as good as those experienced with conventional gravity warm-air systems. In spite of the abrupt 90-deg turns, which were necessary to keep the ducts as high as possible and provide ample headroom, the system was free-flowing. The large circulation of air due to this free-flowing characteristic and the accompanying low bonnet air temperatures were instrumental in maintaining fairly uniform temperatures within the living zone.

The combustion rate, which was regulated by the thermostatically controlled dampers and the barometric regulating damper, was maintained at the minimum necessary to handle the heating requirements of the house at all times. Consequently, the system was economical to operate under all weather conditions.

VIII. Acknowledgments

The results presented in this paper were obtained in connection with the investigation of warm-air heating systems being conducted in the Department of Mechanical Engineering of the University of Illinois under the terms of a cooperative agreement between the Engineering Experiment Station of the University and the National Warm Air Heating and Air Conditioning Association.

This paper is an abstract of a thesis written by Mr. Lamm in partial fulfillment of the requirements for the Degree of Master of Science in Mechanical Engineering in the Graduate College of the University of Illinois.

Acknowledgment is made to S. Konzo, Professor of Mechanical Engineering at the University of Illinois, for his assistance in outlining the test procedure and analyzing the results of the investigation.

VIII. HOT-WATER HEATING FOR BASEMENTLESS HOMES

R. H. Weigel*

I. Introduction

The University of Illinois and the Institute of Boiler and Radiator Manufacturers have been investigating problems in domestic steam and hot-water heating systems in the I = B = R Research Home since its erection in 1940. Its construction[1] was typical of that of the small, well-built American home of that time.

The Research Home was erected with a basement, however; whereas since then, and especially in the past two years, a large percentage of American homes have been erected without basements, on concrete slabs. Floor construction of this sort presented additional problems to the heating engineer, for the concrete, being a good conductor, was an avenue of escape for heat losses, particularly through the edge. Tests[2] in the lavatory of the Research Home showed that a baseboard radiation heating system maintained warmer floors than tubular radiation, and since the floor of the lavatory, which adjoined the unheated garage, was an extension of the concrete floor of the porch and was laid directly on the ground, under conditions typical of those encountered in certain types of basementless homes, additional tests were undertaken during the 1947-48 heating season in one of the University's faculty homes to determine the operating characteristics of a hot-water heating system using cast-iron radiant baseboards in a basementless type of structure. The results of that investigation are described in this paper.

II. Description of Equipment

Basementless Home

The basementless home was of prefabricated construction and was erected on a 4-in. thickness of concrete over a gravel fill laid in direct contact with the ground. Waterproofed building paper was placed between the gravel and the concrete to prevent vapor transmission. One-inch waterproofed board insulation was installed be-

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[1] For construction details of the Research Home see "Performance of a Hot-Water Heating System in the I=B=R Research Home," by A. P. Kratz, M. K. Fahnestock, W. S. Harris, and R. J. Martin. Univ. of Ill. Eng. Exp. Sta. Bul. 349. 1944.

[2] "A Study of Radiant Baseboard Heating in the I=B=R Research Home," by A. P. Kratz and W. S. Harris, Univ. of Ill. Eng. Exp. Sta. Bul. 358. 1945.

tween the foundation and the floor slab and around the periphery of the slab. Heat losses through the slab were based on a factor of 0.06 Btu per sq ft per hr per deg F temperature difference and an indoor-outdoor temperature difference of 70 deg F. The exterior walls of the house were composed of ⅜-in. fiber wallboard, 11 in. of cotton insulation mounted on waterproof paper, an air space, 2 x 3 wood framing members, and ⅜-in. plywood on the outside. The calculated coefficient, U, for this wall section is 0.16 Btu per sq ft per hr per deg F temperature difference. The ceiling was composed of ¼-in. plywood, 2 in. of cotton insulation, and 2 x 4 joists, for which the U value is 0.13 Btu per sq ft per hr per deg F temperature difference.

All windows and doors were weatherstripped, and storm doors were used on both outside entrances. The total heat loss, based on −10 deg F outdoor temperature and 70 deg F indoors, was 42,750 Btu per hr. The total area of the heated space was 713 sq ft and the volume was 5702 cu ft.

Heating System

A wet-bottom cast-iron boiler having a net I=B=R rating of 55,000 Btu per hr and a gross I=B=R output of 84,000 Btu per hr was used in the basementless home. The boiler was supplied with a conversion-type gas burner.

A one-pipe, forced-circulation hot-water system was used in conjunction with type RC, cast-iron radiant baseboards. These units, approximately 7 in. high, were located in the rooms as shown in Fig. 1. Paper-backed aluminum foil served as a dust seal to prevent the possibility of streaking the wall. The radiation in the living room and that in the kitchen were connected in series to form one circuit while the radiation in the two bedrooms and that in the bathroom were connected in series to form a second circuit. The system was designed to operate with a mean water temperature of 215 deg F at 80 deg F indoor-outdoor temperature difference, and a 20-deg drop through each circuit. Three-quarter inch wrought-steel pipe was used in the piping layout. The pipes that were buried in the floor were surrounded with ¾-in. air-cell insulation to permit movement of the pipe where it passed through the floor as the system expanded and contracted; this arrangement also made it easier to connect the radiation to the supply and return piping. Vents were installed at sufficient points to eliminate any air that might accumulate in the radiation or piping.

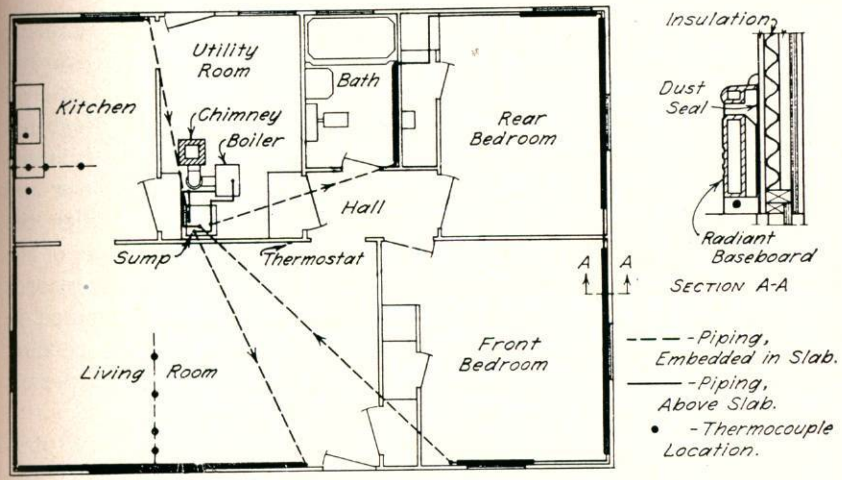


Fig. 1. Floor Plan Showing Location of Baseboard Radiation

Control System

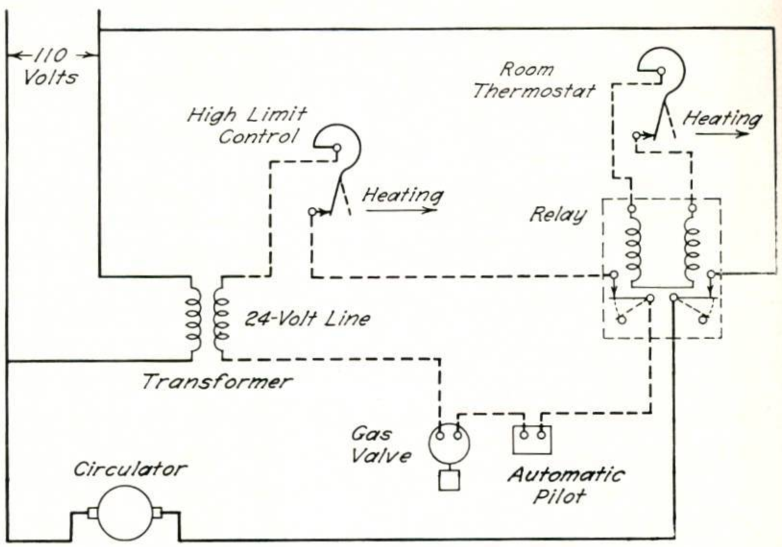
The control system included a room thermostat, a high-limit control, a magnetic gas valve, a safety pilot, a transformer, and a relay. The room thermostat was of the heat-anticipating type and in addition contained provision for making three adjustments of the length of the burner and circulator operating time for a given indoor-outdoor temperature difference. The thermostat was located 30 in. above the floor on the east wall of the living room, as shown in Fig. 1. The high-limit control, which served to prevent overheating of the water in the boiler, was located in the back section of the boiler. The control system and the sequence of operation are shown in Fig. 2.

Testing Apparatus

Three groups of thermocouples were utilized to measure temperatures. The first group was permanently installed in the concrete slab and on its upper surface, as illustrated in Fig. 1, in order to measure slab temperatures. A second group of eight thermocouples was provided for the measurement of air temperatures. Four of these thermocouples were attached to a portable standard at 3 in., 30 in., and 60 in. above the floor and 3 in. below the ceiling. The other four thermocouples were similarly attached to a second standard. A third group of thermocouples was provided to study performance of the component parts of the heating system, including the temperature of the water entering and leaving both circuits, the temperature of the water entering and leaving the boiler, and the flue gas temperature.

A central switchboard was located in the utility room, and all thermocouple leads were connected to jacks on this board. Each hot junction was provided with an individual cold junction maintained at 32 deg F in an ice bath. A portable precision potentiometer and a 10-point recording potentiometer, used in conjunction with the switchboard, provided means for either instantaneous readings of the emf given by any thermocouple and/or continuous printed records of the emf given by any thermocouple except the one located in the smoke outlet of the boiler. The range of the 10-point recording potentiometer was from -1 MV to $+5$ MV, which did not permit recording of the flue gas temperatures.

A 7-day recorder, which was checked periodically with an aspiration type psychrometer, was used to make continuous records of the



Thermostat Calls for Heat:
1. *Circulator and gas burner start.*
2. *Circulator runs until thermostat is satisfied.*
3. *Gas burner runs until thermostat is satisfied or until boiler water temperature reaches setting of high limit control.*

Thermostat Satisfied:
1. *Circulator and gas burner stop.*

Fig. 2. Control System

relative humidity and air temperatures at the 30-in. level in the living room. The CO_2 content of the flue gases was checked periodically with an Orsat apparatus. Self-starting electric clocks were connected in parallel with the gas valve and the circulator motor, and recorded the total time of the operation of each unit during the test period. A gas meter was used to measure the quantity of gas flow to the burner.

III. Test Procedure

A gas-burning rate of approximately 100 cu ft per hr was maintained during the entire heating season. Burner adjustment was such that a CO_2 content of from 7 to 8.5 percent was obtained at the smoke outlet of the boiler. The natural gas used was supplied from the Texas-Oklahoma Pipe Line, and had a high heating value of 1000 Btu per cu ft.

With the house occupied by a staff member, his wife, and one small child, cooking, washing, and other domestic processes were carried on in a normal manner. Little attempt was made to control door positions between rooms. Although the occupants of the house generally kept the utility room door closed, room air temperatures in the rest of the house were not taken until the investigator assured himself that this door had been closed a minimum of 30 min prior to taking observations. Windows remained closed at all times. Observations of room air temperatures at 3 in., 30 in., and 60 in. above the floor, and 3 in. below the ceiling were made at periodic intervals. Approximately every 48 hr the operating time of the burner and the circulator, the cubic feet of gas consumed by the burner, and the floor slab temperatures were recorded. Periodic checks were made of the flue gas temperatures and CO_2. A continuous recording was made of the outdoor air temperature, the temperature of the water at the supply and return connections to the boiler and circuits, and of the relative humidity and air temperature at the 30-in. level in the living room. At all times the thermostat was set to maintain an air temperature of 72 deg F at the 30-in. level in the living room both day and night.

IV. Results

Slab Temperatures

From Fig. 1 it may be noted that slab temperatures in the living room were measured in a plane perpendicular to the west wall and that radiant baseboards extended not less than 7 ft 6 in. on each side of the plane in which the thermocouples were located. Therefore the temperatures measured in this plane were fairly representative

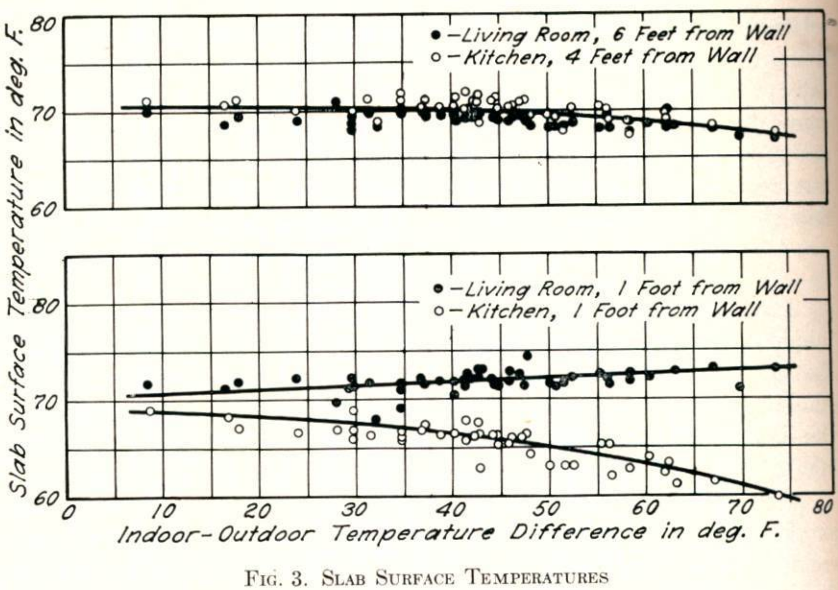


FIG. 3. SLAB SURFACE TEMPERATURES

of slab temperatures that existed in any plane perpendicular to a wall at a point where baseboard radiation was located.

With one exception, slab temperatures in the kitchen were measured in a plane perpendicular to the north wall and with the closest baseboard radiation located 4 ft 9 in. away. These temperatures therefore were fairly representative of slab temperatures that existed in any plane perpendicular to a wall at a point where no baseboard radiation was located.

Figure 3 shows the variation in slab temperatures for the range of indoor-outdoor temperatures encountered during the 1947-48 heating season. The upper curve shows that little variation existed between the average surface temperatures at the approximate centers of the living room and kitchen. Further examination of this curve shows that average surface temperatures at the center of the kitchen and the living room were affected very little over a range of indoor-outdoor temperature differences from 0 to 40 deg F, averaging about 70.5 deg F. For indoor-outdoor temperature differences greater than 40 deg F, the average surface temperature decreased approximately 0.75 deg F for each 10 deg F increase in indoor-outdoor temperature difference. Thus, at the design condition of 80 deg F indoor-outdoor temperature, the average surface temperature in the center of the rooms would be about 65.5 deg F.

The lower curves in Fig. 3 show that slab surface temperatures, 1 ft from the west wall in the living room and 1 ft from the north wall in the kitchen, were markedly different. In the living room, temperatures increased with indoor-outdoor temperature difference as a result of higher water temperatures in the radiant baseboards during the colder weather. This increase was small in magnitude, and the relation between slab temperatures and indoor-outdoor temperature difference was linear. The average surface temperatures were 70.2 deg F and 73.0 deg F for indoor-outdoor temperature differences of 10 and 70 deg F, respectively. In the kitchen, temperatures measured 1 ft from the north wall were influenced primarily by outdoor and indoor air temperatures. Hence, as the indoor-outdoor temperature difference decreased, the surface temperature decreased. Average surface temperatures of 68.8 deg F and 61.0 deg F were obtained at indoor-outdoor temperature differences of 10 and 70 deg F, respectively. If the curve in Fig. 3 is extrapolated to the design condition of 80 deg F indoor-outdoor temperature, an average surface temperature of 58.0 deg F is obtained.

In addition to slab surface temperatures, temperatures two inches below the slab surface were measured at various points in the kitchen and living room. Temperatures 2 in. below the slab surface remained within 2 deg F of the surface temperature directly above. In the kitchen, where the radiant baseboards covered but half of the outside wall exposure, the slab temperatures decreased from the center of the room towards the north wall. The rate of this decrease was found to be a function of indoor-outdoor temperature difference. In the living room, with the radiant baseboards covering all but 3 ft of outside wall exposure, slab temperatures in the center of the room were lower than those near the west wall. Furthermore, temperatures near the edge were higher during cold weather than during mild weather, due to the prolonged operation of the heating system.

An analysis of the data on the study of floor slab temperatures shows that the radiant baseboard is particularly adapted to maintaining comfortable floor temperatures in a basementless type of structure. Surface temperatures in the center of the room were always comfortable and wherever radiant baseboard was installed, temperatures near the edge of the slab were slightly higher than in the center of the room. However, where no radiant baseboard was installed, these temperatures were considerably lower, hence the advantage of radiant baseboard lies in the large amount of outside wall exposure that a long, low unit of this type covers. The insulation at the slab edge also proved to be of value in helping to maintain comfortable floor temperatures.

Room Temperature Differentials and Difference Between Rooms

Air temperatures in the utility room were unduly affected by heat losses from the boiler, chimney, and piping and, unless direct reference is made to the utility room, the following discussion is limited to the other rooms of the basementless home.

From Fig. 4 it may be noted that the average air temperature in the living room at the 30-in. level was almost constant despite large and sometimes rapid variations in outdoor temperature. Temperatures in the living room were approximately 1.5–2.0 deg F higher than those in all the other rooms except the bath. However, the radiation requirement for the bath was based on an 85 deg F indoor-outdoor temperature difference instead of the 80 deg F difference used for the other rooms. Temperatures in the middle of any room, as measured at the 60-in. level, were approximately 0.5 deg F higher than the temperatures at the 30-in. level.

That maximum and minimum air temperatures are affected by the length of the "on" and "off" periods is also illustrated in Fig. 4, a reproduction of the 7-day recorder chart. This was further substantiated by temperatures measured by the thermocouples on portable standards. Figure 4 shows that long cycles of burner and circulator operation, obtained by setting the adjustable differential on the thermostat to position "0," gave a variation of approximately 1.5 deg F at the 30-in. level, that intermediate cycles obtained with the position "B" setting gave a variation of about 1 deg F, and that short cycles obtained with the position "A" setting gave practically no variation.

In Fig. 5, the difference between the average temperature of the air in the center of the living room, as measured at the 30-in. level, and those 3 in. above the floor, and 3 in. below the ceiling, are shown plotted against indoor-outdoor temperature difference. The readings were generally recorded for a duration of only 30 min and without regard to burner and circulator operation. The differentials obtained immediately after the end of an "on" period were at a maximum; those obtained prior to an "on" period were at a minimum. It becomes obvious, then, that more accurate differentials could have been obtained if the duration of the readings could have been extended to cover both "on" and "off" periods of the burner and circulator. This was not possible, however, without inconveniencing the occupants.

Figure 5 shows that the temperature difference from floor to ceiling increased with indoor-outdoor temperature difference. At 69.5 deg F indoor-outdoor temperature difference, the coldest weather at which these temperatures were measured, a difference of only 4.6

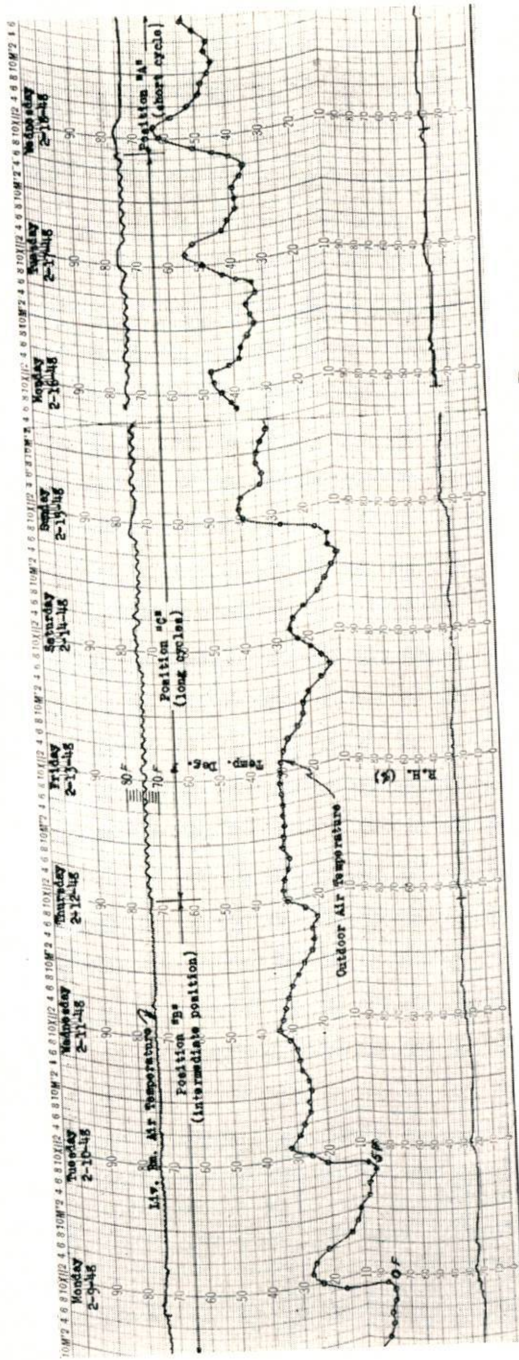


Fig. 4. Air Temperatures at the 30-in. Level in the Living Room

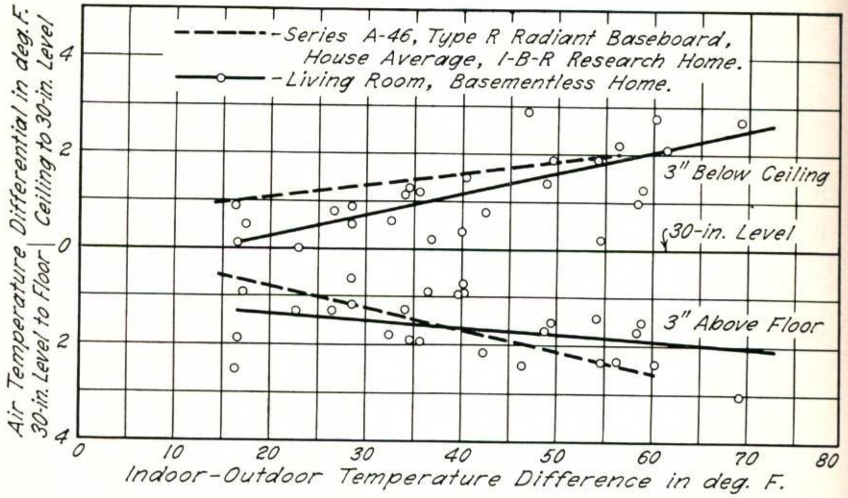


Fig. 5. Air Temperature Differentials

deg F was observed between the average temperature of the air 3 in. above the floor and that 3 in. below the ceiling. For all practical purposes this was about the same as that obtained with type R radiant baseboard in the I = B = R Research Home, as can be seen by extrapolating the curves (Fig. 5) representing the house average of the Research Home.

Average air temperatures in the center of the living room of the basementless home, as measured 3 in. above the floor, were approximately 70 to 71 deg F for all indoor-outdoor temperature differences encountered. In the occupancy zone, 30-in. level to floor, temperature differences were only 1.5 to 2.0 deg F. These results and the results obtained in the I = B = R Research Home[3] indicate that the radiant baseboard, if properly installed, will maintain excellent air temperatures in homes built with basements or in those built on concrete slabs in direct contact with the ground.

Humidity

Humidity observations were made in the basementless home during the 1947-48 heating season with no attempt to increase the indoor relative humidity by means of a humidifier. Curve "A" in Fig. 6 shows the relative humidity observed at the 30-in. level in the living room of the basementless home, curve "B" the relative

[3] "A Study of Radiant Baseboard Heating in the I=B=R Research Home," by A. P. Kratz and W. S. Harris, Univ. of Ill. Eng. Exp. Sta. Bul. 358.

humidity which would have existed in the house if the absolute humidity indoors had been the same as that outdoors, and curve "C" the relative humidity in the I = B = R Research Home[4] with no special means for providing humidification. Each test point represents the average relative humidity for a 48-hr period. The difference between curves "A" and "B" can be considered as representing the moisture added to the indoor air by cooking, by washing, by the occupants, by evaporation from building materials and house furnishings, and by evaporation from water normally used for general purposes in the house, minus that lost to the outside air.

It may be noted that the relative humidities observed in the basementless home and the I = B = R Research Home, as shown by curves "A" and "C," are in fairly close agreement, yet no cooking or washing was done in the Research Home. Although both houses were insulated and provided with vapor barrier paper in the exposed walls and ceiling, and weatherstripping was applied to the doors and windows, the basementless home was not as tight in construction as the I = B = R Research Home. In the basementless home the outside doors and the butted joints of the prefabricated wall panel were

[4] "Performance of a Hot-Water Heating System in the I=B=R Research Home at the University of Illinois," Univ. of Ill. Eng. Exp. Sta. Bul. 349, Fig. 27.

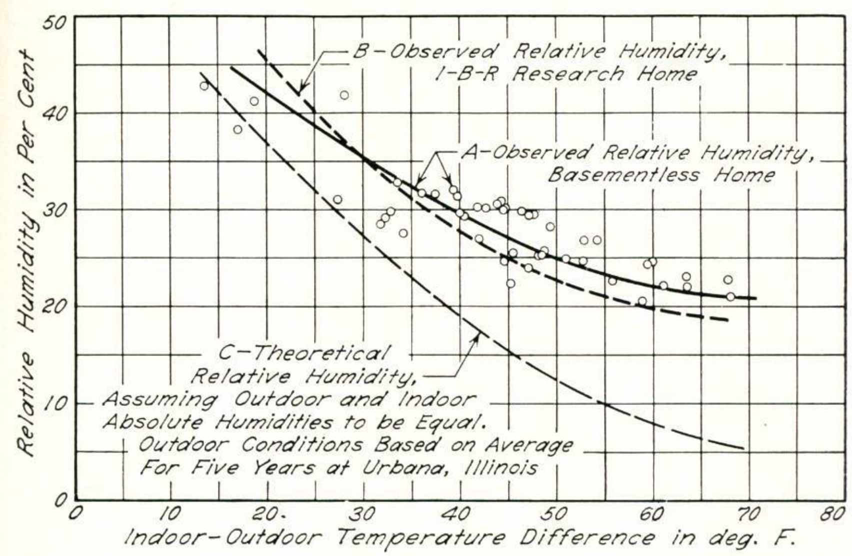


Fig. 6. Indoor Relative Humidity with No Humidification

not tight, and possibilities existed for considerable air leakage and vapor transmission. Thus it is reasonable to assume that had the basementless home been of tighter construction, higher relative humidities would have been obtained. This and other observations[5] indicate that the problem of maintaining adequate indoor humidities for comfort in winter cannot be separated from considerations of good building construction.

Fuel Consumption and Operating Data

Figure 7 shows daily burner and circulator operating time and fuel consumption plotted against indoor-outdoor temperature difference. The data include operation for the three settings of the thermostat differential, at positions "A," "B," and "C." While changes in the thermostat differential had a marked effect on the length and number of operating cycles for any given indoor-outdoor temperature difference, as shown in Fig. 8, it may be observed in Fig. 7 that the setting of the thermostat differential adjustment had no appreciable effect on the daily operating time of the burner or circulator or on the daily fuel consumption.

By extrapolation of the curve for burner operating time, shown in Fig. 7, a total operating time of only 13.5 hr in a day would have been obtained when the indoor-outdoor temperature difference was 80 deg F, thus indicating that the burner and boiler had ample reserve capacity. This belief is further borne out by the rate of climb of the water temperatures at the boiler inlet during the "on" period, as shown in Fig. 8.

Since the calculated heat losses of the I = B = R Research Home and the basementless home are in close agreement, the fuel consumption obtained in the former when using radiant baseboards has been included in Fig. 7. As might be expected, the daily fuel consumption for the two houses was also in close agreement at all indoor-outdoor temperature differences.

Water Temperatures in Boiler and Radiant Baseboards

As shown in Fig. 8, position "A" of the adjustable differential on the thermostat gave shorter "off" periods and "on" periods, and hence more cycles of burner and circulator operation for a given indoor-outdoor temperature difference, than did position "C." It may also be noted that boiler inlet water temperatures for position "A," at 36.5 deg F outdoor temperature, varied from 110 deg F to about 140 deg F, a range of only 30 deg F, while water temperatures for

[5] I=B=R Research Digest No. 9.

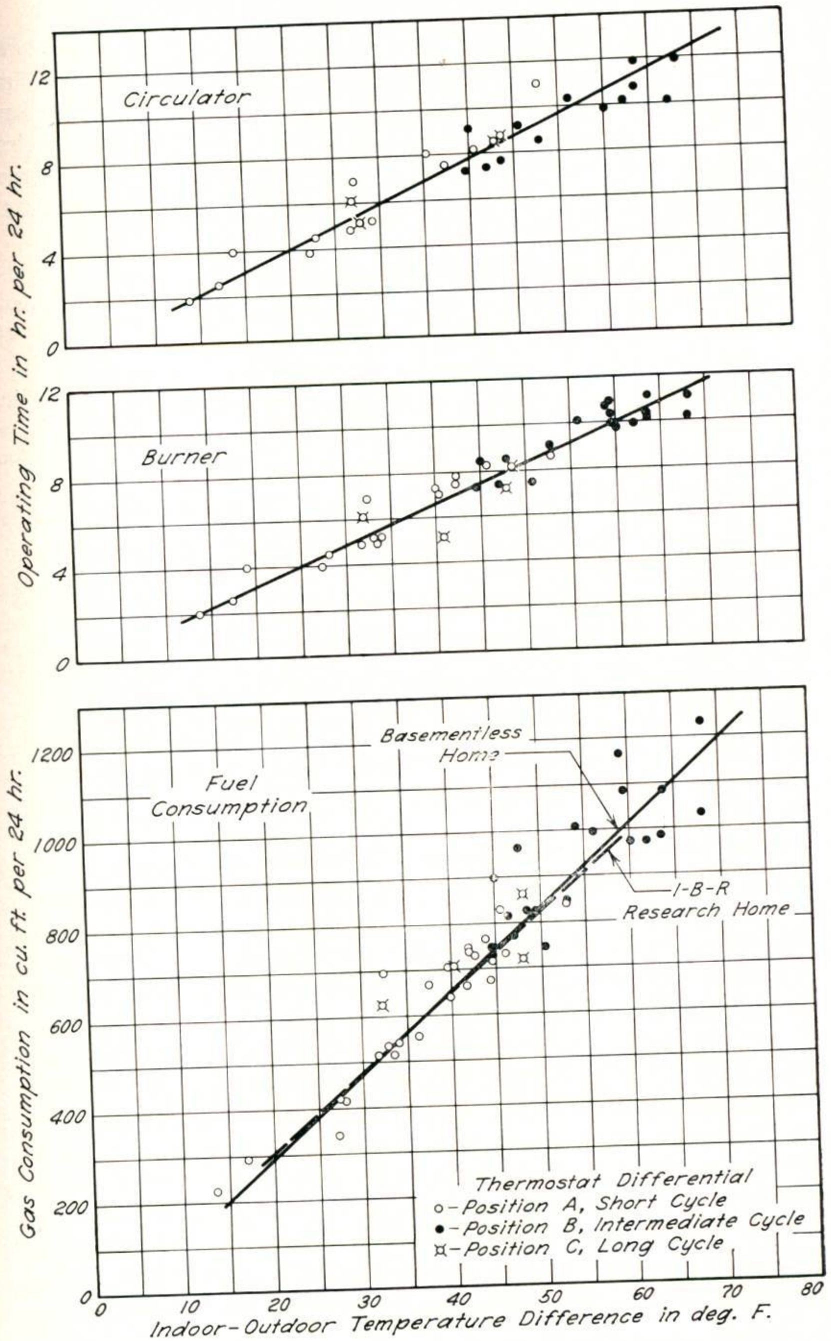


Fig. 7. Boiler and Circulator Performance

position "C" varied from 102 deg F to about 191 deg F, or a range of 89 deg F. These ranges of water temperatures at the boiler inlet are fairly indicative of changes in water temperatures in the baseboard radiation. Thus, with the shorter cycles of burner and circulator operation smaller fluctuations occur in the water temperatures for the radiant baseboard and hence small variations occur in the surrounding air temperatures.

Curves 1 and 2 in Fig. 9 show the water temperatures obtained at the boiler outlet and return connections at the end of the circulator "on" period, whereas curves 3 and 4 show these temperatures at the beginning of the circulator "on" period. The arithmetical average of curves 1, 2, 3, and 4 is represented by curve 5, which for all practical purposes represents the average temperature of the water in the boiler for any given indoor-outdoor temperature difference. It is also representative of the average water temperature in the radiant baseboards.

The radiation installed in the basementless home was just suffi-

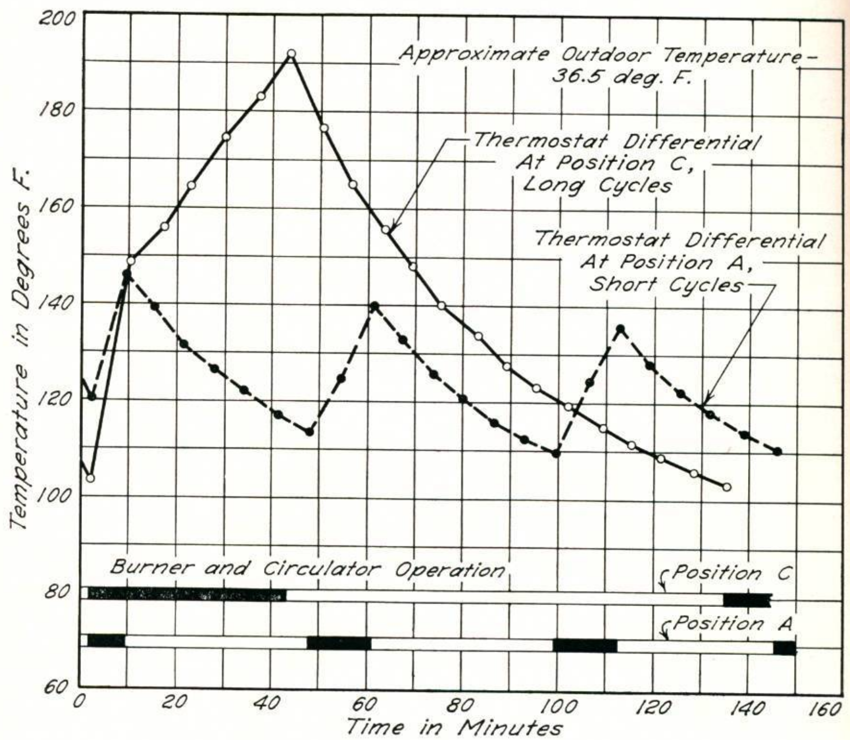


FIG. 8. BOILER INLET WATER TEMPERATURES DURING "ON" AND "OFF" PERIODS

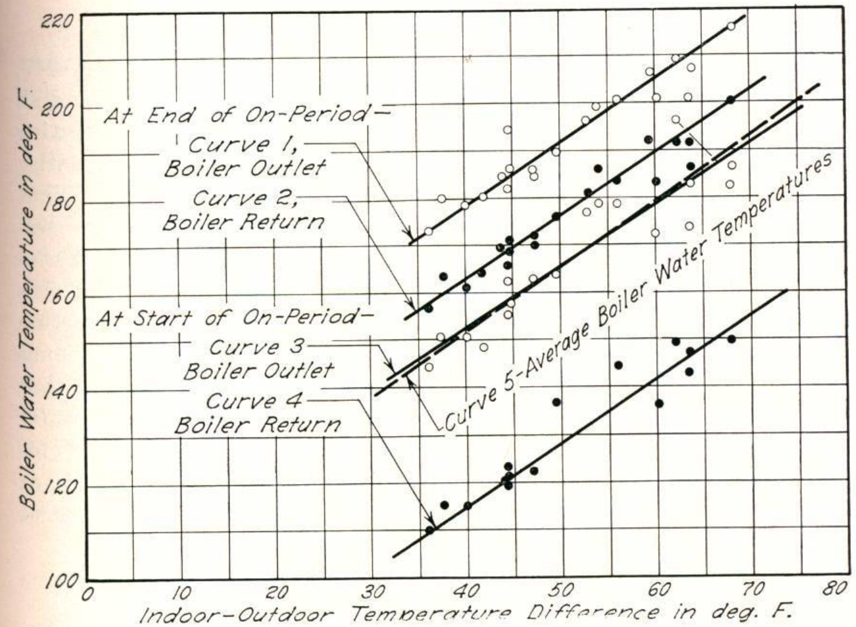


FIG. 9. BOILER WATER TEMPERATURES

cient to offset the calculated heat loss at an outdoor temperature of −10 deg F when the radiant baseboards were supplied with an average water temperature of 215 deg F. It may be noted from an extrapolation of curve 5 in Fig. 9 that when the indoor-outdoor temperature difference was 80 deg F the average boiler water temperature would have been 205.5 deg F and the average water temperature in the radiant baseboards, which was essentially the same as the average boiler water temperature, would have been 9.5 deg F lower than that selected for the design of the system. This seems to indicate that the amount of radiation installed was sufficient to carry the load at design conditions but that the margin of surplus radiation was small.

Temperature drops through the boiler and circuits were measured when the system was operating around design conditions. A temperature drop of 11.8 deg F was obtained in the bath-bedroom circuit, a drop of 9.8 deg F in the living room-kitchen circuit, and a temperature rise through the boiler of 12.2 deg F. Since the heating system was designed on a 20 deg F temperature drop, these data indicate that in each circuit the flow was more than ample to take care of the radiation connected to the circuit.

Cleanliness of Operation

The basementless home was ready for occupancy in May, 1947, and when heat was applied, all the walls were freshly painted and all the curtains and draperies were clean and new. After operating through a complete heating season of approximately nine months, faint dirt patterns were observed on the walls above the radiant baseboards. Curtains and draperies that hung over the radiant baseboards, however, were as clean as similar curtains and draperies under which no radiant baseboard was located. The dirt patterns were the result of dust being carried close to the walls by convection currents and being deposited by thermal precipitation. Experience in the I = B = R Research Home and elsewhere has indicated that these dirt patterns may be eliminated by reducing the design water temperature in the radiant baseboards to 200 deg F or lower. This decreases the amount of convection currents set up by the radiant baseboards and hence the magnitude of the temperature gradient near the wall.

V. Summary and Conclusions

A summary of the test results of this investigation and the conclusions that may be drawn are as follows:

1. The radiant baseboard is particularly adapted to maintaining comfortable floor slab temperatures in a basementless structure, because long, low units of this type cover a large percentage of outside wall exposure.

2. Insulation at the slab edge proved to be of value in helping to maintain comfortable floor temperatures.

3. Average air temperatures, as measured 3 in. above the floor, were approximately 70 to 71 deg F for all indoor-outdoor temperature differences encountered when the thermostat at the 30-in. level was 72 deg F.

4. Temperature differences between the occupancy zone, as measured 3 in. and 30 in. above the floor, were only of the magnitude of 1½–2 deg.

5. Fuel consumption was not affected by the setting of the adjustable differential on the thermostat; however, water temperatures in the radiant baseboards, and consequent fluctuations in room air temperatures, were affected. The longer lengths of the "on" and "off" periods of the burner and circulator resulted in greater fluctuations of room air temperatures.

6. Faint dirt patterns were observed on the walls above the radiant baseboards after nine months of operation. Dirt patterns of this type can be eliminated by limiting the design water temperature to 200 deg F or lower.

7. The problem of maintaining adequate indoor humidities for comfort in winter cannot be separated from consideration of good building construction. At 10 deg F outdoor temperature, 22 percent relative humidity was obtained in the basementless home and 20 percent in the I = B = R Research Home, yet no cooking or washing was done in the latter.

IX. AIR POLLUTION CONTROL

Louis C. McCabe*

Smoke regulations have been in force in American cities for a hundred years and more. Fifty cities had such regulations by 1924, but enforcement generally has not been effective because of public indifference, interested opposition, or an incompetent or unrealistic approach to the problem.

Because of its unique position as the seat of the Federal Government, lack of industry, and nearness to anthracite and low volatile coals, Washington, D.C., has long been a model smokeless city. St. Louis was the first industrial city in the United States to put into effect far-reaching regulations for control of smoke. These were retained throughout the war although there was much pressure to relax them. Since 1945 other cities have been active in smoke abatement. Pittsburgh has completed its first year with powers to regulate the volatile content of domestic coal. Cleveland, Detroit, Columbus, Cincinnati, Milwaukee, Philadelphia, and New York, to name a few, have initiated or intensified their smoke abatement programs.

In common with many other expanding metropolitan areas Los Angeles has experienced an increasing nuisance not from smoke alone but from atmospheric contamination by fumes, gases and dusts. The name "smog" has been applied to this complex of atmospheric contamination which frequently limits visibility to a few blocks and causes eye, nose, and throat irritation. It attained objectionable proportions in the early years of the war and, in response to public demand, the 1947 session of the California legislature added comprehensive statutes to the Health and Safety Code[1] for the purpose of controlling it. The Act recognizes that the problem is broader than "smoke abatement" and provides that the Board of Supervisors of any county, on finding that serious "air pollution" exists, may establish a county-wide district to control it and may pass such supplementary regulations as are required. The standards now in effect and the regulations that may develop out of the work of the Los Angeles Air Pollution Control District are of interest beyond the area to which they apply, because they are concerned with these broader aspects of air pollution. However, they are not capable of adoption by other communities without regard to local conditions.

Topographic and meteorological factors are important in any scheme of air pollution control. If our cities could be planned with

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this in mind we would have less objectionable air contamination, but such planning is rarely possible. Favorable weather conditions may permit the release of air pollutants in one area which could not be tolerated under less favorable conditions at another place.

Topography and meteorological conditions[2] have a great influence on air pollution in the Los Angeles basin. High mountain ranges surround the city on the north and east. Prevailing daytime winds during most of the year are westerly or southwesterly. Average wind velocity is less than 6 mph. These on-shore "sea breezes" move gently over the area from 8:30 a.m. until midnight. During the night a light land breeze develops which moves down the mountain valleys toward the seacoast at less than 1 mph. In the summer and early fall, temperature inversion limits the vertical distribution of the atmospheric pollution, and the local winds move it over the area from the west during the day. If it does not escape through the mountain passes, it returns on the night breeze to be reinforced by the next day's contamination.

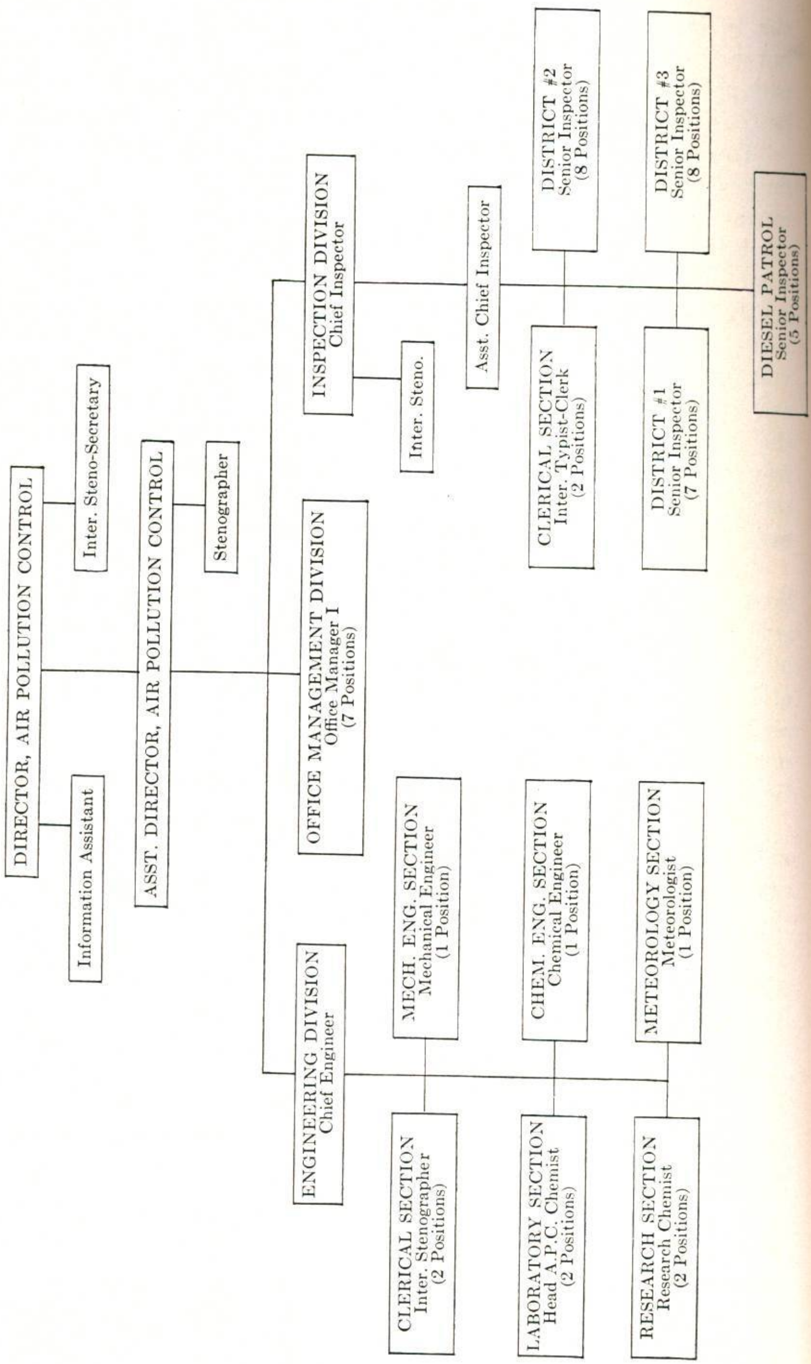
The inversion layer is very resistant to turbulence and acts as a lid to hold the pollution near the ground. Visibility is greatly restricted at times of low inversion, and eye and throat irritation are at a maximum. This brief discussion of meteorological phenomena of Los Angeles is to point out the need for fundamental data on air pollution control. Detailed meteorological information, though not available for many areas, is essential to successful air pollution program.

The Air Pollution Control District is charged with the enforcement of certain well-defined statutes. Success depends on effective organization and on the approach to the problem. Figure 1 illustrates the organization of the Los Angeles Air Pollution Control District.

The inspection division of the District is concerned primarily with the prevention of visible smoke, fumes, and dusts. These come from the improper burning of oil in stationary boilers and ships, foundries, lumber waste incinerators, oil-burning locomotives and diesel trucks, the open burning of household and commercial rubbish, 300,000 backyard incinerators, and smudging in the citrus groves during a few nights in the winter.

Continuous policing of the nineteen inspection districts of the county by the inspectors has a beneficial effect in encouraging "good housekeeping" on the part of the plant operators; but the primary function of the inspection division is to act as the training and intelligence unit of the District. Through patience and demonstration many plants are brought over to good operation.

Fig. 1
Air Pollution Control District Organization Chart



New or complex problems encountered in the field are brought to the engineering division by the inspectors. That division is divided into the operating permits, industrial standards, and research sections. Regulations adopted in February 1948 provided that all existing industrial plants would operate under blanket permits but that new or altered equipment thereafter installed would be required to submit plans for approval before construction and that a final inspection of the completed installation must precede issuance of a permit.

Standards limiting stack emissions to 0.035 grains per cu ft for lead and zinc oxide and 0.4 grains per cu ft for particulate matter (60 deg F and 14.7 p.s.i. pressure) were adopted last February. It was indicated, however, that the limit on particulate matter was established for the control of fly ash from the burning of sawdust and other wood waste. Lower limits will be set for ferrous, siliceous, and other dusts when a survey of existing installations is completed. The ferrous and nonferrous foundries are at present making extensive tests to determine stack loadings and the nature and size distribution of dusts going to the atmosphere. Thirty-seven nonferrous foundries jointly financed the technical survey of their furnaces, and more than 60 gray iron foundries are represented in the preliminary testing and pilot plant operation which the Gray Iron Foundryman Association is undertaking in cooperation with the Air Pollution Control District.

Two chemists and a meteorologist constitute the research staff of the district. Research contracts for specific investigations are placed with the local universities as required. The district also retains four consultants. Their specialties embrace photo-chemistry and microanalysis of gases, absorption spectra, scientific instrumentation, treatment of waste gases, sulfur chemistry and that field of meteorology concerned with the size and identification of minute particles of solids and gases occurring in the atmosphere.

On August 14, under the guidance of Professor H. F. Johnstone of the University of Illinois, we first collected the aerosols (droplets) which constitute the liquid phase of the smog. This was done with the cascade impactor, which deposits the particles of different size on glass slides placed in front of the four jets of the apparatus. Continuing this work, on several days we have collected for 24 hr continuously. Chemical tests show the material to contain sulfates and to be acid in character.

The greatest quantities of sulfur compounds are released to the atmosphere in the Los Angeles area from the refineries and chemical plants and the burning of fuel oil by other industries. The sulfur balance supplied me by the petroleum industry some time ago indicates that 822 tons of sulfur dioxide enter the Los Angeles atmosphere each day. Twenty-two tons of this come from gasoline burned in automobiles and 12 tons are released by the burning of diesel oil.

The fog-forming qualities of SO_3 (sulfur trioxide) and sulfuric acid mist are well known. That sulfuric acid is formed by the oxidation of sulfur dioxide in sunlight has been demonstrated by British[(3)] and German[(4)] chemists. We have repeated these experiments here and find that if a flask filled with sulfur dioxide is left for as long as 20 min in the sunlight a fog of sulfuric acid mist is formed. The extremely low visibility that begins two or three hours after sunrise when the humidity is too low for natural fog is very probably due to this formation of sulfuric acid mist.

We have collected smog at stations set up north of Long Beach, in the industrial city of Vernon, downtown Los Angeles, and in the vicinity of the Rose Bowl in Pasadena. It is our observation that heavy concentration occurs earliest in the morning at the first station and moves on through the others in the order named as the southwest-to-west wind pattern is established.

The first half of September was a period of relative calm wind accompanied by temperature inversions with their base near the ground. This condition concentrates the smog in a thin layer along the ground. August 21 to September 4 was marked by extremely heavy pollution. About 60 percent of the refining capacity in the area began closing down, because of a strike, on September 3 and was in standby condition on September 5. Although meteorological conditions during the week after the beginning of the strike were not the same as the week before, there were days of low inversions. However, the visibility was much better and the pollution was less intense. The clarity of the atmosphere on the leeward side of the idle refineries was in striking contrast to that of the operating plants.

Our observations are that sulfur compounds contribute in great measure to the smog. The removal of sulfur gases from industrial stacks is by no means an easy problem to solve. A few of the refineries in the Los Angeles area now recover hydrogen sulfide economically and thus reduce the sulfur dioxide going to the atmosphere. Another chemical plant is scheduled for completion by January 1 which will process 50 tons of hydrogen sulfide daily, thereby reducing the amount of sulfur compounds in the atmosphere. However, I do not believe this goes far enough. Because of climatic conditions in the Los Angeles basin, we must apply strict standards comparable to those established by the London County (England) Council. We are continuing our work on sulfur and hydrocarbon compounds. Cheap ammonia would make it possible to use the ammonium sulfate or the ammonium sulfite-bisulfite process to remove sulfur dioxide from stack gases. Ammonium sulfate for fertilizer and liquid sulfur dioxide produced by these processes should find a ready market. Efforts are being made to obtain an ammonia plant for Southern California.

In his presidential address[(5)] to the American Chemical Society in 1928 Professor S. W. Parr said: "While we have made marvelous advances in cures for human ills, in bacteria control, in hygiene and sanitation, so far as water and waste are concerned, sanitation of the air stands today just where it did one hundred years ago." We have not made much progress since Professor Parr said this, but there are indications that a change is taking place in the public mind regarding air pollution. Those of us working in this field still find a great lack of organized information worthy of general application. Therefore we borrow techniques and adapt equipment which have been developed in other fields. Much of the data that is published is not properly correlated and interpreted. For example, we find voluminous tabulations of sulfur dioxide concentrations without significant information on humidity or wind movement. Compilations of this nature are but the hod-carrying of science. It may be possible to erect a structure from such information but the possibilities are remote.

The University of California at Los Angeles last year offered the first college-level course that has come to my attention on the Control of Industrial Smoke, Dust, and Fumes. It embraces origin of dust, fume, and smoke; abatement codes; sampling and measurement of smoke, dusts, and fumes; principles of combustion; combustion equipment, design of furnaces and incinerators, theory and function of chimneys; settling chambers; centrifugal dust separators; bag houses; electrostatic precipitators; gas washers and scrubbing towers; reaction towers for neutralizing noxious fumes; and economics and utilization of byproducts. It was so successful that it has been offered again this year.

We have great need in this country for a scientific and technical organization devoted to air pollution research, in the broadest sense. It should be adequately financed so as to be free of public and private pressures. In addition to research activities, it would develop standards for the measurement and control of air pollution, whether from the combustion of fuels or from the products of atomic fission. It would be a center for gathering and disseminating knowledge on all phases of air contamination. It would thus be useful to the public and to industry.

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X. CHANGING CUSTOMER RELATIONSHIPS

Don Snell*

In looking through old papers recently, I found a New York and Erie Railroad timetable for 1854. Directly under the heading were these two amazing sentences: "This Time Table is not intended for the information of the Public, nor as an advertisement of the Times or Hours of any Trains. The Company reserve the right to vary from any of them, *at their pleasure*, and will not be responsible for any information herein contained."

Remember the days when coal offices hung out shingles saying "Coal Orders Accepted Here?"

This morning we are to think together about "Changing Customer Relationships." "Customer" in this paper means the family unit — the home-owner or renter or flat-dweller who buys fuel for his family's needs for heat, hot water, and cooking. We are not here concerned with fuel needs for income-producing properties or power loads. The customer is the person who plays the most important role in the business equation, the woman or man who should be present at every Board of Strategy meeting of your firm and mine. Unfortunately, in too many such meetings the customer is not only absent but not even in the thoughts of the "Big Brass." We tell the chauffeurs and hikers in our company that our customers are the ones who pay them their wages, not the company.

"Relationships" I take to mean those between the retail coal merchant and his customer as just defined. The word "changing" threw me at first. I wasn't sure whether the planners of this Short Course wrote it down as an adjective or a verb. Did they mean that customer relationships have changed or that we as coal merchants are supposed to change them? Both interpretations seem possible. Let's take changing as an adjective first.

To talk about changes that have taken place in customer attitudes, we must take a point in time for the basis of our comparison. I have no intention of going back to the days of the Franklin stove. Will you settle for the turn of the century? Fifty years seems a good round period. I have no desire to bore you with my life story, but to illustrate a few points, I would like to compare the house in which I lived as a boy, in central New York state, and the one I now live in near Chicago.

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You have all seen houses like the first one — large rooms, high ceilings, drafty floors, no insulation, no weatherstripping, no storm sash, Aunt Martha's bedroom that refused to get warm on cold days if the wind was in a certain direction. We had a hot-air furnace, a hard-coal stove to heat two rooms on the basement level, and a coal-burning cook stove, which also heated the water for the tank. I remember how pleased my father was in 1910 after he tried out furnace coal in place of egg coal, at the suggestion of his coal dealer. In 1911, he bought a thermostat, the first one in town. It was noisy but it worked. That same summer he bought a Maxwell touring car. It had what was inaccurately termed a "one-man top," which usually took three men and the wife of one of them to get it up. I am bringing in the Maxwell because I would like to have you contrast it with the car you are driving today, and then think about progress in the auto industry from 1911 to 1948 compared with progress in our industry. If we suffer comparison, can we find reasons and remedies?

All of you have also seen houses like the one in which I now live. It has six rooms, not as large as those in the other house, with low ceilings, is completely insulated and weatherstripped, has some storm sash, and is a completely comfortable home in which to live both summer and winter. There are no drafty floors. If Aunt Martha were still with us, her room would be as comfortable as the rest of the house. Cooking is done with gas, but we still use coal for heating and our hot-water supply.

We have agreed to limit our discussion this morning to the family customer and we have focused our attention on the time element, fifty years ago compared with today. At the turn of the century, coal supplied 88 percent of the total energy requirements of the United States. Last year it supplied 50 percent. Now I would like to put a geographical limitation on your thoughts, by telling you that I am speaking in terms of the state of Illinois only. Will any of you challenge the statement that coal has lost the cooking load in Illinois? Will you dispute the statement that coal is losing the hot-water load? That leaves the heating load for consideration. The all-important question then is this: is the trend in heating Illinois homes away from coal?

Perhaps you and I and our customers would all prefer to live in a climate where we could have twelve months of 70-deg temperatures without any effort on our part. But since we live in a state where degree-day totals range from 6400 to 3900, we have to provide means for keeping comfortably warm from September through May. If our customer is lucky enough to have a house or a flat in which to live, he and his wife must decide which fuel to use.

Their choice can be made from:

1) Coal (or Solid Fuels, if you prefer the broader term)
   - hand-fired
   - stoker-fired
   - burned in a pulverized coal burner
2) Oil
   - a natural petroleum product
   - a synthetic
3) Gas
   - natural
   - manufactured
   - or bottled
4) Wood
5) Electricity, including radiant panel heating
6) Heat pump
7) Solar heat
8) Atomic energy
9) What else?

Our Illinois customer who has to make a decision in 1948 or 1949 will undoubtedly choose among one of the first three — coal, oil, gas. I would of course like to be able to say that he will most certainly choose coal. But will he? How many customers and prospective customers in your community are burning coal because they prefer it to other fuels? Treat them well; they are the best of friends. How many people living in apartments who want to get in a house where they will furnish their own heat will decide in favor of coal? How many young people planning marriage and setting up housekeeping will decide in favor of coal? The only decisions here that really count in our favor are those made for coal after the customer has fully weighed the merits of all three fuels.

The next class of persons to consider includes those who are now burning coal, but only because they cannot get gas or fear the oil shortage. These are still our customers; but we cannot count on their staying with us, should our competitors get in a position to supply the demand for their products and services.

The third class includes those now using competitive fuels. Can we win them back to coal?

When our customers and prospects can get any fuel, will coal place first, second or third in their choice? Our goal as retail coal merchants must be this: to look forward to a time when we can come to meetings like this and say to each other, honestly and sincerely, "We've got the fuel the home-owner wants."

All right, what does he want? He wants push-button heat. Do you blame him? I don't. Are we able to give it to him? No. Will we be able to give it to him? I hope so. People may have been willing to put up with the discomforts that went with home-heating fifty years ago; they may have been willing to contend with the difficulties of automobile travel forty years ago. But inventors and engineers have given us performance and comfort in our autos undreamed of forty years ago. By the same token, people now want to get their homes heated by manipulating a gadget on the wall.

Good merchandising involves knowing not only how customers' desires *have changed* but also how customers' desires *can be changed* to accept the product or services one has to sell. When my father's coal dealer suggested a change in size of coal, he not only was rendering a modern service to his customer but was at the same time removing himself both in time and thought from the "public be damned" attitude expressed in that 1854 New York and Erie timetable. When, a year or two later, he sold father a thermostat, he was really changing from just a coal dealer to a coal merchant.

I would define a coal *dealer* as one who is content to take an order for coal, deliver it, and get paid for it.

I would define the 1948-model retail coal *merchant* as one who does all or at least most of the following:

1) Buys the coals that will give customers in his community the best value for their money.

2) Has a wide-awake, courteous and responsive office force, trained to take orders over the telephone in a pleasing manner. (It makes no difference whether the office force numbers one or fifty.)

3) Checks the heating plant before making a delivery, to be sure he recommends the right kind of coal. It is at this point that the alert salesman can render a real service to his customer by pointing out the importance of the *whole house* in his quest for comfort. Here is the time to talk about insulation, weatherstripping, caulking, storm sash, storm doors, proper-fitting windows and frames, and all that sort of thing.

4) Maintains his truck or trucks in the modern manner — i.e., keeps them well painted, attractively lettered, in good repair.

5) Makes his deliveries in the most progressive manner that conditions in his community will permit.

6) Has his drivers and hikers in uniform, and trained to do a neat, efficient, courteous job.

7) Calls back after the delivery, especially the first one, to make sure it was made properly and to instruct the home-owner in the best ways to get maximum value from the coal.

8) Makes sure the customer pays promptly according to the prearranged terms.

9) Makes available to his customer technical help in solving his heating problems.

10) Gives his customer seasonal advice about cleaning his heating plant, replacing filter pads, repairing worn parts.

11) Carries on a well-planned advertising campaign.

12) Takes an active part in association work, because he realizes that group action can accomplish more for him than lone-wolf tactics.

This adds up to something most remindful of Coal Heating Service, doesn't it? I mean it to do so, for it seems to me that this program is well worked out and when executed on a larger scale should do big things for the retail coal industry.

You will say that there are many retailers in Illinois who fit my definition of a coal merchant. I agree with you. Compared with its own performance of fifty years ago, the retail coal industry has progressed. Compared with its competitors, has it progressed enough? Not if I read the trends in public desire correctly!

If you agree that something more must be added if we are to keep our present customers happy with coal and get coal in the new homes, what will we add?

I have two suggestions to offer.

The first is *Research*. Do you know of any pool of money for research raised by retail coal men to improve retail coal's future? The nearest approach that I know of is the Small Homes Council work here at the University of Illinois. My hat is off to them and the work they are doing. But I would like to see the retail industry more deeply interested financially and administratively.

One happy result of a well-planned research program might be a solution of the ash problem! It might even be that some fine day we could look our customer in the face, smile and say: "Sure, Mrs. Alexander, you can heat your home with coal next winter and you and your husband can lock up your house for the month you spend in Florida." Research, basic and applied — and the University of Illinois has had wide experience with both kinds — can get to some such goal within the next few years if we will only provide the funds to hire the talent. We can spend pennies per ton now to save a market already ours, or lose it and then belatedly spend dollars per ton to win it back. Which choice shall we make?

We have been thinking together for several minutes now about customers and their desires. Let me ask you at this point how you account for changes in customers' desires? Did the car owner of 1912 go to his dealer and say, "Instead of this top that causes me so much trouble whenever I want to put it up, I want one that will go up by pushing a button?" Of course not; the 1948 convertible top was the result of research and invention. Tires that lasted three thousand miles in 1913 were good tires; today you expect to get more than thirty. How do you account for the progress? Research and invention. You can add your own items to the list. In a radio discussion late in 1944, Eric Johnston, then president of the United States Chamber of Commerce, made this statement: "Our fastest growing companies in America spend about 3 percent of their gross receipts on research."

The research I have just suggested would be carried on by trained men hired by us to do the job. It would be a long-range program, and the results might not be apparent at once. But in the meantime, we can and must do a better job of training ourselves to be better merchandisers of coal. This involves my second suggestion, which is *Education*.

Research can solve technological problems. Education can solve human-relations problems. In the field of human relations, I include both the working out of harmonious relations between management and workers within a business organization and the working out of harmonious relations between that organization and its customers. More and more, business has turned in recent years to the universities for help in this field. In Chicago last year we used the Extension Division of the University of Illinois most successfully in an opening course. We are following that course with another one this year. My personal guess is that others will follow.

Let me sum up this paper for you quickly. History does not tolerate industries that put roadblocks in the path of progress. Only by being progressive can we succeed in tomorrow's market. It is my firm belief that retail coal can build its own future. If we make a better mouse trap, the world will not beat a path to our offices, but we can send ourselves and our salesmen out to the world with the knowledge and the tools to do the job we all expect to accomplish.

XI. WHAT'S BEHIND THE HEATING DIFFICULTIES AND COMPLAINTS

ROBERT F. MILLIGAN*

Our subject for this session reminds me of the story about the old mountaineer who went to the circus and saw an elephant for the first time. After studying the animal from all angles the old resident finally said, "It can't be, but there it is." Some of the complaints we receive are in the same category as the elephant. However, let us not forget that when customers register a complaint they feel that trouble is, or has been, brewing and they want help.

Let us now consider detailed difficulties and complaints on domestic jobs as they have been met during years of service work.

1. *Coal Won't Burn*

The customer usually means the coal doesn't burn as well as previously. This condition may be due to lack of draft, improper firing methods, or perhaps change in burning characteristics of coal delivered compared to previous deliveries. Wrong size of coal may also be a contributing factor.

With stoker firing the complaint may be caused by the stoker windbox being full of riddlings, burned or clogged tuyeres, stoker air control stuck, or perhaps very dirty fan blades. Very wet coal will also result in the complaint. On several occasions stoker fans have been found running backward after motors have been repaired. With ratchet gear cases the stoker will feed coal with reversed motor rotation but the fan will not supply sufficient air to burn the coal.

2. *The Fire Goes Out*

Usually caused by improper firing methods such as extremely thin fuel bed in mild weather on handfired jobs. Most customers have to be convinced that during milder weather the best practice is to let ashes build up on grates and to carry a thin layer of active fuel over the ashes instead of trying to control a thin active fuel-bed on the grates.

Wrong size of coal may result in a smothered fire or the reverse, a wide-open fuel bed, and may cause the "fire out" complaint. Lack of air over the fire, or a tight basement, or a combination of both may smother a fire. Improper banking methods or a poorly fitting draft door or damper may cause a fire to burn out over night.

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On stoker-fired jobs the "fire out" complaint may result from any of the following conditions: fuse blown or switch off, coal arched in hopper or over feed-worm in a bin-fed stoker, pin sheared or overload tripped out, hold-fire control set improperly or not operating, gear case belt slipping or worn out, fire dirty or choked with ash, excess stack draft causing fire to burn out with normal hold-fire setting or improper fuel-air ratio. Extreme crushing of coal due to worn stoker parts and/or wrong type of coal for the particular job might result in fire going out.

3. *Bad Clinkers*

This condition is often the result of: burning garbage in the heating unit, extreme stirring of the fuel-bed (mixing ash with burning fuel), improper operation of drafts (i.e., wide-open and then shut tight), excessive shaking of the grates, forcing the fire to bring up heat fast, or trying to make an undersized heating unit carry the load. Using coal too small in size or with ash fusion point too low for the particular job also results in clinker complaint. Ash accumulation under the grates, and/or burned grates, cause improper air distribution through grates resulting in clinkers.

In addition, on stoker-fired jobs troublesome clinker formation may be due to: tuyeres burned and/or windbox partly plugged with siftings, causing extremely high burning rate on parts of stoker; operating with draft over fire too low or with pressure over fire. Lack of air supply due to dirty fan blades will also contribute to clinker complaint.

4. *Coal Gas or Objectionable Odors*

This complaint is usually due to one or more of the following causes:

(1) Gas passages, smoke pipe, or base of chimney partly full of fly ash or soot.

(2) Damper fouled or slipped on shaft.

(3) Down-draft. (Because top of chimney is too low or growing trees affect draft.)

(4) Improper location of check damper. (It should be between the chimney and the hand-turn damper.)

(5) Cracked fire pots.

(6) Leaks between sections in furnace.

(7) Insufficient draft due to cracks or holes in smoke pipe and chimney, and also to leaky joints at chimney and cleanout door.

(8) Cold, damp chimney causing lack of draft. (This condition usually shows up in late spring or early fall.)

(9) Ashpit section cracked or burned through.

Improper firing methods such as smothering the fire, charging the fire with check open or turn damper throttled, or banking with ashes may also cause gas trouble. Operating with fire door slide or wicket closed tight may result in smothered fire, with gas complaint.

A dry humidifier pan with an accumulation of lime, scale and dirt may cause foul odors in the home. These pans should be removed and cleaned periodically.

Gas from red-hot clinkers removed in stoker operation may also lead to a complaint. Whenever possible the clinkers should be allowed to partly cool off before being removed from the firebox, and closed containers should be used to hold clinkers.

Gas or smoke from the fire door, with stoker operation, may be due to lack of overfire draft or to excessive forced draft. The smoke-pipe draft control and also the stoker air control should be checked to be sure they are operating properly.

5. *Stoker Hopper Smoke*

The most common causes of this complaint are: fire not properly cleaned; coal too coarse or wet, causing arching over the feed worm in the hopper; fire burning too low in the retort; feed worm and housing badly worn; smoke eliminator, tuyeres or windbox partly plugged; lack of overfire draft due to dirty flues, smoke pipe or chimney, or perhaps to air leaks along the line; excessive air from stoker fan due to improper setting of fan damper, or automatic air control perhaps not working properly. Also, if the stoker has a sealed hopper the gasket may be defective. Improper assembly of stoker parts such as lack of a sealing compound at the retort joint or wrong placement of blind tuyeres may also lead to hopper smoke.

6. *Excessive Ash*

This complaint may easily develop with a change in coals or sometimes even with coal from the same mine. Although a shift in the ash content of 2½ percent by weight, from say 5 percent to 7½ percent, may seem minor to the average dealer or service man, such an increase means 50 percent more ash to a customer.

The complaint may be due to the customer's shaking the fire too much or to bad grates allowing small-size fuel to fall through.

Naturally, weather conditions may result in more ash with hand firing or more clinkers with a stoker, due to colder weather causing increased use of fuel. We should keep a table of normal percentage of fuel consumed by months, for quick comparison with changes in degree–day data, and should be able to explain to a customer how and why degree–day comparisons are made.

There are times when, due to a change in coals, we must be able to explain to a customer how the ash bulk may increase without appreciable increase in actual weight of ashes per ton of coal burned.

With stoker firing the ash complaint may be due to too frequent cleaning of the fire, a condition which does not allow clinkers to form properly.

7. *Burning Too Much Coal*

A call on this item may result from improper firing methods, change in coal, or the customer's unfamiliarity with the fuel being used. Changes in the heating system such as bad air vents, dirty filters, blower blades fouled, dirty boiler or furnace, or perhaps partly fouled warm-air leaders or cold-air returns eat into the fuel pile. A sudden temperature drop outside or an extended spell of cold weather can easily cause excess fuel complaint; here again the degree–day comparison is useful.

Improper setting of controls, particularly on forced warm-air and hot-water jobs, often causes excess fuel consumption. Moreover, the air-fuel ratio out of balance on stoker jobs can eat a big hole in the coal pile.

Failure to consider the effect of forced draft on some of the older boilers may also cause excess fuel consumption. Whenever possible the gas travel should be lengthened, by proper baffling, when mechanical firing is adopted.

8. *Not Enough Heat*

This difficulty often accompanies the "excess fuel consumption" complaint. The two items are tied closely together, and the various check points listed above should be reviewed.

In addition many gravity warm-air jobs have been installed and some are still being installed, with inadequate cold-air returns or with heat traps in some warm-air leaders, caused by dropping a leader pipe under a floor beam, etc.

Some cases require a thorough check of heating equipment for size of boiler, furnace, or installed radiation.

We also meet the diverse heat requirements of various age groups.

Consider likewise the age and condition of the building; perhaps a caulking job is needed, or storm sash or insulation.

Naturally we check the size and quality of coal delivered, as shipping clerks sometimes make mistakes.

Fuel-bed plugged with clinkers due to laxity in cleaning fire, with a stoker, in severe weather, is a common failing and always produces a heat complaint.

Too low a setting on the limit switch for severe weather may cause lack of heat. In extreme cases the main switch may be off or a fuse blown.

From the foregoing you will notice that the "excess fuel consumption" and "lack of heat" complaints may require a complete check from basement to chimney top in order to run down the trouble satisfactorily and completely.

9. *Overheating*

A call on this complaint is usually the result of improper firing methods such as wide open draft; fuel-bed too thin (not enough ash on grates); or lack of proper control of draft due to leaks around warped draft door, warped ashpit door, or leaks between boiler section and boiler base. In a handfired domestic plant it is only natural that in most cases, under manual operation, the fire will overshoot the heating requirements in mild weather. A set of automatic draft controls, properly adjusted, will go a long way toward eliminating this overheating. We must not forget also that the use of wrong-size coal may result in inability to properly control the heat.

With stoker firing the "excess heat" complaint may often be traced to any one or a combination of the following: coal feed rate too high, hold-fire control set improperly, thermostat setting too high or differential too wide, thermostat in a poor location, limit switch set too high (most stoker users forget to change the limit switch setting or have never been instructed in the proper use of the limit switch). Or we may have a case of badly coking coal filling the firebox with "coke trees" and then "taking off" after a short running period on a heat demand.

10. *Coke Trees*

This problem, although tied in closely with the inherent burning characteristics of the coal, may be aggravated by any of these conditions: fuel-bed too thin; excess chimney draft; air leakage low in the retort; preheating of coal in the feed tube due to solid hearth fill with little air circulation around the windbox and feed tube; excessive wear of feed screw and tube, causing extreme crushing of coal, and finally burned tuyeres with air chamber partly filled with siftings, causing uneven air distribution and perhaps a red hot retort. Often a customer is comparing the conditions of his fire with that of a neighbor who may be burning an extremely different-acting coal under widely different operating conditions.

11. *Explosion or Flashback*

This sometimes serious call is usually the result of improper hand-firing procedure. The fire box may be plugged or the fire smothered; gas passages fouled; the fire checked too soon after charging fresh fuel; or lack of overfire air. With stoker firing the trouble may be due to burned tuyeres, allowing raw coal or dust to accumulate in the windbox and then hot ash to drop down and cause gas accumulation; or perhaps the customer tried to rush the fire by throwing a shovel full of coal through the fire-door on top of the stoker fuel-bed. Lack of overfire air will also cause a flashback at times with stoker firing.

12. *Dusty Coal*

There is no excuse for delivering dusty coal on a domestic job. If the coal is not properly treated at the mine the retail dealer should certainly treat it before delivery.

However, a nearly empty coal bin often collects a lot of dust due to coal breakage or other causes, and if proper precautions are not taken a fresh delivery might be condemned for the dust that is raised because of a dirty bin.

In addition, many dust complaints are due to improper handling of ash or clinkers by the owner, to leaks around the furnace casing, or to dirty filters. One of the older furnaces has a dust or fume pipe connection between the ashpit and the furnace-door sill. This pipe may leak or be out of place, allowing dust to go up into the living quarters.

13. *Spotty Heating or Stratification*

During a call on some other item we often find that the customer has difficulty in obtaining uniform heat or that the occupants are subjected to that "below-knee cooling" sensation.

This difficulty may be due to:

(1) Extreme variation in heat output caused by improper regulation of drafts.

(2) Poor distribution of heat into the room as a result of improperly covered radiators or of furniture so placed that the normal flow of heat from radiators or low registers is disrupted.

(3) Thermostat differential set too wide.

(4) Thermostat affected by the close proximity of a lamp or radio.

With forced warm-air we frequently run into the complaint of stratification because many people have the mistaken idea that the circulating fan should run as little as possible. Naturally, with the circulating fan not running the heat flow from registers ceases almost immediately and cool air cascades to the floor and stays there. With the blower off for an extended period the cool-air layer gradually becomes thicker and the room occupants develop the "refrigerated knee" condition. Finally the blower starts, and the thick layer of cool air is whipped up into a draft.

Obviously, to prevent such a condition the blower should run as nearly constantly as possible. To do this the blower control normally has to be reset to limits which amaze the average home-owner, and in many cases blower speeds have to be reduced. The blower-speed reduction can usually be sold to the customer by explaining how the fan speed affects the power requirements (i.e., power required varies as the cube of the speed). The blower should deliver a steady flow of warm air to heat the home properly, with constant blower operation when outside weather is at design conditions. Under no conditions should the blower deliver hurricane blasts of *hot* air. This means that in addition to proper setting of the blower control we must also, in most cases, lower the setting of the furnace limit switch.

Naturally we should check the location of registers, and of air direction from registers, to be certain that room occupants are not affected by high-velocity air streams.

Finally, because many jobs have been turned into complaint-producers by dirty filters, it is too bad these important parts of the system are not out in a glass case where the home-owner could see them whenever he passed the furnace.

Conclusions

A summary of the various heating complaints would indicate the following approximate percentages:

6 percent due directly to coal
48 percent due to faulty equipment
46 percent due to improper firing or handling of heating equipment.

With these percentages in mind it appears that we still have some ground to cover in selling customers on the advisability of proper heating-plant maintenance. There is also much room for better education of employees and our customers on the proper utilization of the fuel delivered and the proper functioning of the entire heating plant to insure heating comfort. Too much "first aid" has been administered to sick heating plants, and not enough expert diagnosis and cure.

I would like to offer as a closing thought. "A careful summer inspection may prevent a winter Solid-Fuel rejection."

XII. THE ECONOMICS OF MECHANICAL COAL HANDLING

(A Synopsis)

KENNETH H. MYERS*

How many of you coal dealers deliver with a horse and wagon?

Then I shall assume you are all progressive men, interested in more efficient operation of coalyards by the use of the latest methods.

I shall not try to cover the whole field of mechanical handling but shall treat only that which I am best equipped to comment on — portable conveyors.

Equipment must be of the best quality, well designed and expertly built. Price alone is not the governing factor. Machine A at $1000 is cheaper than B at $800 if A will handle 100,000 tons before repairs are needed, or at a conveyor cost of 0.001 per ton, while B will need extensive repairs at 40,000 tons, at a cost of 0.005 per ton—five times as much as machine A.

The type of equipment used is an important factor. Should we buy one large conveyor at $3000 or three conveyors at $1000 each? If the use of one big machine ties up trucks and men while moving from location to location, it is an expensive piece of equipment! Tonnage delivered at low manpower cost is important. Check your operation for lost time and you will go for smaller, more mobile equipment. Truck costs per hour are important; therefore, idle time should be checked. You may find that a cost of thirty cents a minute is not uncommon.

Delivery from trucks is also important in order to retain and gain customers. Quick, efficient placement of coal in customers' bins, with a minimum of mess, is to your advantage. It soon pays for itself, in view of trimmer and hiker rates per hour. Quick truck turnaround will also reduce costs.

A typical survey may be enlightening. The data in column A below refer to deliveries made with two Ford and three Chevrolet trucks. The loads were typical domestic, commercial, and industrial. The yard has one large, self-propelled conveyor and truck chutes. The data in column B were gathered when the same trucks and crews were used but four small yard conveyors and five truck conveyors were employed.

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	A	B
Tons per truck per day	20.5	28.7
Weight per load, average	4.1	4.1
Miles per ton	1.33	1.35
Minutes per ton	0.24	0.16
Minutes per load	0.98	0.64
Miles per gallon	4.94	4.82
Cost per ton—driver	0.528	0.384
Cost per ton—truck	1.12	0.86
Fleet delivered—tons	102.5	143.5

You will note 41 additional tons delivered — about $80 additional profit. Therefore the $6000 additional investment in conveyor equipment paid for itself in 75 working days. It continued to run for 618 working days without repairs. Was it a good investment?

Savings were made by quick truck turnaround. The drivers were happier, and proud of their equipment. Customers were pleased to deal with so progressive an organization. Consequently it was good advertising and made for better customer relations. Also, the morale of the drivers picked up in the process.

Truck conveyors were left on the job till it was completed, and in one case two conveyors were used in tandem to deliver a job that had been wheeled.

Equipment investment is economical and results in more satisfactory operation. It is depreciated against income, allowing a capital gain that is retainable. When equipment becomes costly to repair, it should be scrapped and a new cycle begun. In manufacturing, it is necessary to write off equipment and invest in equipment that will result in a savings of only a few pennies per produced item. Coal dealers can simply compute savings, write off equipment quickly, and then depreciate it over a period of years. Most coal-handling equipment will pay for itself in a few months of operation, whereas manufacturing equipment may take five years to be written off.

XIII. BUYING AND SALES APPEAL OF COAL, REGULATORS, AND STOKERS

P. O. Wiechers*

Our company has been working closely with retail dealers who have been merchandising all coal-heating accessories that give greater comfort and satisfaction to the consumer. During the postwar years the sale of these heat controls — stokers, coal stoves, shovels, furnace cleaners, and the like — depended much on a sufficient supply of coal to satisfy the domestic market.

The retailer's commonest remark has been, "Why should I sell coal-heating accessories to help coal when I can't even get enough coal to satisfy my customers?" With rare exceptions today, there is enough coal for everyone; no one need use supply as an excuse for not using his best efforts and directing his attention to the sale of accessory equipment. In fact, today we must begin to think about means of moving coal, for all the yards I have seen lately are crammed full of all grades of domestic and industrial sizes. We must get out and work and sell again. No more mere order-taking.

Everyone knows the standard sales-appeal phrases:

1) Abundant helpful uniform heat — a constantly radiating fuel bed.

2) No drafts and chilly floors; no on-again off-again fuel.

3) Three thousand years' supply.

4) Adaptability to any degree of automaticity — handfired with heat regulator, hopper stoker, bin-feed stoker.

5) Far more economy than fuel oil and gas when considered on equal terms of the weather-conditioned home.

6) Greatest safety factor of all fuels: easy to handle, easy to regulate, slow to ignite; will not, in its normal state, leak or explode.

7) Visible storage supply which assures heat and solid comfort with solid fuel all winter long.

8) Ability to burn anywhere — is the most flexible fuel on the market; grate stove, furnace, stoker, without elaborate attention or adjustment.

But if we are to maintain our position as America's Number 1 home heating fuel, we're going to have to tell even more than this sales story.

* Assistant Sales Manager, Red Jacket Coal Sales Company, Columbus, Ohio.

Our greatest buying appeal centers about a complete heating service. The next few years will be a battle of the services. The man who, having a good coal, gets there first with the most services will be the man who increases his business and the sale of his product.

Our competitors continually have to guess about their reserves, and keep changing their figures. You know, however, that it will take more than reserves to sell our product.

Here are a few of the things that I see as creating a desire for coal. I start with the first impression you get when you see a coal truck on the street delivering a load to the consumer.

Clean Delivery Equipment

We need lots of window dressing outside the office, in which the public seldom gets except by phone. A million dollars' worth of free advertising is wasted every day by unpainted delivery trucks running up and down the streets of this country. A local coal association, a state association, a national group like Coal Heating Service, should be able to develop a seasonal or monthly series of sales messages which should be told to the consumer coast-to-coast and advertised from the sides of every truck, just as cigarette companies and other advertisers utilize the billboard space on Railway Express trucks. Look at the construction of truck bodies. They are moving billboards. Today there is one thing we want to tell the domestic consumer, "Lay in your coal." Why shouldn't 50,000 or 100,000 coal trucks all over the country be carrying that same message. Let's think and coordinate on a nation-wide basis, for our industry moves by seasons and this kind of advertising will pay dividends.

Some of you are saying that you have your name and phone number on the truck in big letters. What of a word about your product? Something that would influence the user in Maine, Ohio, Illinois, or the Dakotas, something that would convince your customer he is right in using "Solid fuel for solid comfort." We need to give a good first impression, and the truck seems to be a fine place to start our talk about quality, service, dependability, and the modern convenience of our product.

Clean, Courteous Delivery Personnel

Shoveling coal is a dirty job, especially on a windy day; but a uniformed driver with a delivery cap and a decent pair of coveralls is a good start to confidence. When he stands to get the delivery ticket signed, the customer thinks, "If those fellows who deliver

my coal are that clean looking, they must have pretty clean coal on that truck."

Your driver is your daily source of direct relationship with the public, pedestrian and consumer alike. He can be important in building goodwill by following, practicing, and improving in these nine basic factors discussed below.

Personal Appearance

Every good driver will take pride in his work. So he should carefully consider his personal appearance, the first thing people notice about him. Good appearance also gives him a degree of confidence when meeting others.

It is expected that an efficient, progressive dealer will send out clean, neat representatives. A uniform cap with the "CHS" button, a pair of good overalls, and perhaps an arm patch with the firm's name makes a practical uniform. Along with that should go a fresh shave every morning.

Pleasant Face

The driver need not be a Clark Gable but he can flash a sincere smile, a smile reflects pleasantness. Your customer must be considered as a friend, and there is as much reason to smile sincerely at a business friend as at a personal one. The secret lies in being pleasant *all* the time.

Friendly Voice

First impressions are important: a friendly voice that carries a naturally pleasant tone when talking to the boss — your customer. Cordiality is another essential. Equally important is the use of tact and judgment in what is said, to eliminate misunderstandings.

Adaptability

"Adaptability" covers a number of things a driver can do to give better service. He can see that the shovel, broom, poker, and other utensils are left in their accustomed place, that the flower beds and shrubs are undisturbed, that basement window and door are closed, that the premises are clean inside and out when he departs, that any damage is called to attention before delivery, and any new breakage reported immediately. The good driver is one who can apply knowledge of human nature and of men's peculiarities, to the end that he is congenial with and helpful to each patron. Clean, courteous, careful, alert — these all are encompassed in adaptability.

Enthusiasm

The sale is not completed when the dealer takes the initial order. From that time on, the driver plays an important part by helping to keep your customer sold on your product. The driver must, then, be customer-conscious, service-conscious, and enthusiastic. The enthusiasm he displays is certain to be reflected in the customer's attitude. Obviously you must first develop within your driver an enthusiasm for the company, its products, its service, and its policies.

Knowledge

A good driver should be alive to every opportunity to increase his knowledge of the product. Though not expected to be conversant with the technology of coal, he should possess certain items of information. He should know that there is no finer, more economical, more dependable heat than automatically fired coal; that an overfed stoker requires free-burning, high-fusion-point pea coal, and that an underfed stoker must have a high-grade, bituminous, low-fusion-point coal of finer consistency; that coal is oil-treated, not to increase its heat value but to allay dust; that "arching" or "bridging" in the hopper is due to excess moisture and can be greatly eliminated by summer "fillup." With such knowledge the driver can enlighten both his customer and outside acquaintances.

Consideration

All too many truck drivers, like many taxi drivers, have been inconsiderate of pedestrians and private drivers. The acts of the driver are often viewed as the attitude of the company. Everywhere, consideration is vital in building goodwill.

Sincerity

All goodwill efforts fail unless promoted by sincerity. Sincerity yields confidence, and public confidence is the cornerstone of your business.

Interest in the Customer

"Good morning, Mrs. Smith" indicates a degree of interest in the person addressed—first because an effort was made to learn her name and second because the name was used in friendly greeting. Changes in a customer's basement, home, or yard, such as a new furnace or stoker, an enlarged coal bin, a newly painted or re-roofed house, are worthy of note if the opportunity naturally presents itself.

In short, good coal, clean equipment, and efficient deliveries are essential to your coal business. But they alone are not enough. To

hold and increase your business you must instill in the buying public the desire to buy from you, not just once but time after time. How do you do this? By goodwill, that intangible something you can't buy. Goodwill is earned — earned by attention to details, by the interest displayed and the service given in your daily contacts with your boss — your customer — the public.

Are you holding employees' meetings? Are you helping them to do a better job? You yourself know the answers; do your drivers know them? It's your job to tell them.

Your driver is your representative. He is your public relations man. Help him be a better one by attention to the little things that count. Do that and your organization is on the road to gaining a real asset . . . GOODWILL.

"Truck to Bin We Chute It In"

We can't overstress the importance of clean delivery methods. The closer we come to dustless delivery the greater our customer's satisfaction. Thinking dealers today are carrying water-spraying tanks that can be strapped on the driver's back so that he can go down into the basement and spray the bin with water before delivering coal. Nine-tenths of the time it is the old, dry dust in the bin that is stirred up by the delivery of the new coal.

Ash-Removal Service

This is a controversial subject. Ash-removal service is a continual source of irritation to some dealers, but it is a service which is here to stay and bound to grow in some communities.

A number of communities provide an ash-removal service without charge; others, a scavenger service. But on the whole, ashes constitute a major problem when placed behind the home.

Till recently, I never realized how many retailers are offering ash-removal service.

There is one simple answer to this problem which we of the bituminous industry have never investigated thoroughly but which has received much study in the anthracite industry. That is a gravity ash-removal method whereby any quantity up to a season's supply of ash is stored in a pit beneath the heating plant. The plant of the future must furnish this accommodation. George Woodruff, retail dealer of Bridgeton, N. J., has had much experience in the construction of these pits and has made about 500 installations. Trade journals have carried articles about them. Those of us who are concerned with the domestic coal market must do honest-to-goodness thinking and sensible planning for ash-handling and storing facilities, because probably from 50 to 90 percent of those who have changed to competitive fuels have done so on account of the problems attendant on handling ashes in the basement and disposing of the ash from coal. Anyone who burns coal would appreciate having, beneath the furnace or boiler, a pit large enough to hold a season's supply of ash. When the heating season is over, the retail dealer could have a steady summer job for his winter deliverymen by giving an ash-removal service at a charge. Scarcely a coal-burning home owner would be unwilling to pay for this service, and I shall be glad to direct you to the proper authority to receive complete information on construction of these pits.

Ten million of these in American homes would be 10,000,000 satisfied users and 100,000,000 tons padlocked.

A Hopper-Tending Service

This service is valuable to elderly people, others working at odd hours around the clock, and the infirm and physically handicapped. It gives everyone, regardless of his age or work or physical condition, an opportunity to burn coal.

A Degree-Day Delivery Program

Any retail dealer can understand the degree-day system and put it into effect. A one-man organization can run the system as well as a large organization. Spend a few days learning the theory, and 30–60 days setting up and getting into actual operation. A fundamental is the development of a telephone personality and sales technique. The man who anticipates his customer's needs under this type of program will keep competition away and will always have his customer's bin filled.

A Summer Heater-Conditioning Service

This service is essential to year-after-year coal satisfaction. It can bring additional income at a season when sale of coal normally drops. So it tends to reduce overhead and give steady employment to drivers and yardmen, increasing their value as sales and service personnel too. Anyone who can drive a truck, observe traffic signals, obey ordinances, and deliver coal can control the nozzle end of a vacuum cleaner. "My drivers aren't intelligent enough to clean a furnace" means that we do not want to spend the time to teach them properly or that our business does not yet need these means to show a profit. Or else we have not seen the value of year-'round employment to keep our organization together and thereby protect tonnage and increase income.

Followup and Counselor Service

Any organization can inaugurate this service. Sale of supplementary equipment gives full opportunity to pay for followup, and it is an invaluable aid to any business to be able to say "Thank you for the order" in person, properly regulate the air on the new stoker coal just delivered, leave a firing chart, and offer suggestions for firing the new coal. Why not also leave a small colorful picture and diagram for construction of a dustproof bin, and estimated cost; or pave the way for selling and installing a heat regulator or stoker; or sell a replacement furnace or boiler, hot water circulating pump, or hot water heater? Commissions on these items will pay well for time spent.

Insistence on proper coal- and ash-handling tools in the customer's basement, though often neglected, is vital. Fifteen minutes spent showing the customer the value of proper tools and methods may bring big repeat orders for years to come. As an industry we must, on a nation-wide scale, educate customers in using shovels sized to fit the feed door and in the proper ways of removing dust and ashes.

A 24-Hour Emergency Service

Such a service is given by more than 1500 retail coal dealers. It is fundamental to the continued sale and use of coal in the domestic market. Because of the stress that Americans place on "service," how long can the industry refuse to satisfy the pleading of coal users everywhere for assistance in times of emergency and distress?

Selling Equipment that Gives Greater Comfort and Satisfaction with Coal

We have presented a complete heating service as the primary buying and sales appeal on coal and have taken the viewpoint of the consumer. We have purposely not discussed many things you have stressed for years—the dependability of your source of supply, the uniform quality of your product, the economy and comfort it yields. You are all well grounded in that story. The customer takes these virtues for granted and assumes them to be characteristics common to all coal and to every coal company. Service now becomes the all-important buying and sales appeal on coal.

Two other items worthy of mention along with a complete heating service as sales appeals are the value of a visible reserve supply of unfailing heat, and the safety factor in coal that is not present in oil or gas. We should stress both these, and particularly the safety of coal. Watch the headlines this winter; compare the number about explosions and fires caused by ignorance, negligence, or faulty gas- and oil-heating equipment with the few where coal is used.

Now let's look at heat controls and stokers. During the past three years some dozen sales and producing companies have concentrated on the sale of thermostatic damper regulators to retail coal dealers. Most of these companies are tied in with the nation-wide distribution of a regulator especially designed for the retail coal industry. Today more than three thousand men are selling this regulator alone.

Sustained interest in regulators and stokers within the coal industry has been kept alive by, and is due to the pioneering of, many men too numerous to mention here. There is at present a revival of interest in the sale of heat regulators, not only by nation-wide groups and the Chicago Retail Coal Merchants but by thousands of small retail coal dealers in every area in the bituminous market.

These men know that through the sale of thermostats and stokers they are enriching their business possibilities and protecting their future coal market. You recall the success which the anthracite industry has had in equipment sales by vigorously pushing the sale of heat regulators over the period of the last decade.

Every buyer of a heating accessory, particularly a thermostat, will give the dealer a testimonial. Yet some dealers fail to exert a sustained selling effort, because in the past the coal business has been a one-man business conducted on an order-taking basis rather than as a contact-and-sales operation. Most of us feel that our business is becoming more sales-conscious. When we all recognize that regulators are as much a part of the retail business as maintaining a stock of coal or a modern delivery service, there will be a new level for coal merchandizing. Then the sale of regulators and stokers will skyrocket and carry with it complete consumer satisfaction.

When producers and retailers alike realize that the home owner's concept of comfort and convenience has changed and that thermostatic temperature regulation is as much a part of this age as the automobile, we will make real strides in heating with coal.

Every gas-heated home has a thermostat; every oil-heated home has a thermostat. Why shouldn't every coal-heated home have a thermostat? Either we provide a thermostat for every customer or we will find them going over to some other kind of fuel.

Nor must we forget the regular sheet metal and heating dealer. He has always pushed the sale of regulators, and by his efforts a great coal market has been preserved. Greater things are yet to come through the cooperative efforts of the heating dealer and the coal man to sell automatic coal heat. A large regulator manufacturer says his sheet metal and heating dealers now sell a regulator with every new furnace.

The coal industry heartily subscribes to a program of "a heat regulator on every handfired furnace." Other manufacturers say their heating dealers seem to be doing a better job of selling new installations. We can say that the sheet metal and heating contractor has done a better job of merchandising regulators than the retail coal dealer.

The control industry is developing a plan whereby the coal dealer and the heating contractor may work together on a joint program to sell controls. I believe we can expect this program to be given an impetus by Coal Heating Service in the near future. We have developed a slogan, "Let the man who sells you coal Furnish you a heat control." The slogan is on every die-cut display board that accompanies each Step-Saver Heat Control Demonstrator.

The slowdown of the oil industry and restrictions on use of gas give the most ideal set of conditions for the sale of coal regulators and coal stokers. We should take advantage of this situation and sell hard. One or two years of real equipment merchandising now will pay off in a decade of repeat business and untold years of consumer satisfaction.

What does it take? Industry-wide knowledge of and agreement on the basic buying and sales appeals of regulators and stokers, and positive selling action by everyone in the coal and heating industry.

What are the big sales appeals? Here are some you can use.

A heat regulator provides uniform heat at any desired temperature, day or night, without any effort.

It keeps a low fire going in spring and fall weather much more easily than could be done by constant attention.

It prevents overheating but keeps a steady flow of heat in cold weather.

It makes the furnace last longer by preventing burned-out and warped castings.

It saves many steps to the basement or to hand-regulated damper controls.

You can get up in a warm home in the morning and return to a warm home any hour of the day or night.

It conserves coal.

It promotes health through proper temperature in homes.

There are other important features that help sell regulators.

For example, demonstration panels permit you to take the regulator into the prospect's home to show the complete unit in action.

Some regulators have a plug-in connection. Some can be installed by the home owner himself. The trend today is toward the plug-in unit. The unit itself, in some instances, costs the consumer as little as twenty dollars. To bring automatic coal heat to renters and others who handfire, do not overlook the plug-in control.

Other regulators have a built-in rheostat which reduces the current to 12 volts and eliminates the transformers. Others have damper motor and plug-in transformer mounted on an easy installation board ready to tack to the joist or rafters.

All regulators are self-lubricating. The limit controls are interchangeable, and the thermostats have all the latest operating features.

All regulators are packed in an individual carton, and are a complete packaged unit with all necessary accessories — wire, chain, pulleys and screws, and an easily followed illustrated installation instruction sheet is included.

How Retail Coal Dealers Sell Regulators

In helping dealers, we have found that one of the greatest things they need is a way of carrying the story of the heat regulator to the consumer. As an experiment we delivered a small-scale ticket sticker to a handful of retail dealers, to see whether the stickers would create interest in a regulator if they were attached to the delivery ticket and sent along with a load of coal. Favorable reports led us to circularize our whole list, tell them the story, and enclose a sample sticker with the offer of a 30-day gratis supply. About 100,000 are now in use, and we are getting repeat orders every day.

We have also found that retail dealers vary greatly in their methods of selling thermostatic damper regulators. One Akron dealer has sold more than a hundred by merely demonstrating them from the regular display board to people who came in to buy coal. A Columbus retailer employed Ohio State University students on a commission plan and had them make door-to-door demonstration and solicitation of his customers. He preceded this with a letter asking customers to show the students the courtesy of listening to their story. In not over ten weeks he sold 85 regulators. In addition, dealers have made many sales by persistent, intelligent telephone contact and personal solicitation. One Cleveland company, during the summer slack time, had its key office-man contact the trade in person, soliciting heat regulator sales. The Champion Coal Company of Pittsburgh has sold over 500 heat controls of one type alone in little more than a year by demonstrating the regulator in their sales office to every person who comes in to order or to pay his bill. Their activated display board is a real credit to them. One ambitious retailer in another city sold more than

50 regulators to a contractor constructing a housing project, and now contemplates selling this contractor 100 more for a whole subdivision now being built in a large Chicago residential district.

Buying and Sales Appeals on Stokers

Let's keep telling the story of stoker-fired coal heat. A coal stoker offers many more advantages than oil and gas in comfort, convenience, cleanliness, freedom, economy, safety.

Today people want the abundant life, lots of play, little work, more money; it is only natural that the constant attention required by handfired, manually controlled furnaces must give way to the ease of automatic firing by stoker or at least to a thermostatically controlled handfired furnace. The appeal to the abundant life is the one we use in selling stokers and regulators. It works every time.

We must try to incorporate into our business, more and more, the sale and service of coal, regulators, and stokers.

We will work with any retailer who is interested in incorporating these services into his business.

This industry needs loyal, stout-hearted men who are willing to work together for the advancement of the industry in the domestic market. All of us, naturally, must burn coal. We must each be so inspired with our product and with our knowledge of our product that we set an example and can say, "Do as I do because I know — I burn coal." Coal is king. Let's serve him.

XIV. WHO BUYS STOKERS AND HOW TO SELL THEM

Ray Harnetiaux*

From the beginning of the stoker industry up to the present day, about 1,400,000 stokers have been installed.

Up to 1930	10 000	1939	104 289
1930	1 179	1940	152 825
1931	12 121	1941	192 447
1932	9 521	1942	88 000
1933	18 233	1943	32 839
1934	28 704	1944	42 958
1935	47 926	1945	130 834
1936	86 080	1946	190 917
1937	101 808	1947	67 700
1938	96 433	1948	......

Oil- and gas-burner and burner unit sales were as follows.

Oil		*Gas*	
Up to 1946	1 985 000	Up to 1946	1 108 000
1946	500 000	1946	395 000
1947	900 000	1947	92 000
1948	400 000	1948	90 000

Of the gas units sold up to 1946, California accounted for 490,000.

What do these charts mean?

First, notice that the stoker industry was on an even keel till 1947. In that year, oil and gas tied us in knots. The reason: no salesmen.

The oil shortage was responsible for an upward curve in stoker sales in 1948. Will it last? No. Not unless we stop waiting for our competitors to run out of ammunition. We must re-learn to close our own deals.

What is the potential of the central-heating field?

1. Dwelling units in the United States — 40,000,000.
2. Central heating plants — 18,000,000.
3. Stokers, gas-burners, and oil-burners installed — 6,000,000.
4. Central heating plants handfiring — 12,000,000.
5. Percentage of central heating plants being fired with coal—74%.

What percentage of the twelve million handfired plants will we stoker in the next five years, and what will we lose to gas and oil? The answer depends on two groups: the manufacturers of stokers; and you men — the coal dealers. Sale of stokers is an integral part of your business. You can't afford not to be selling stokers.

There are 14 million more family units than in 1940, and 11.7 million more people. There have been 25 million babies born in this country since 1940. The number of Americans has reached a new record of 143.4 million.

* Domestic Sales Manager, Stoker Division, Fairbanks, Morse & Co., Chicago, Illinois.

Standards of a decade ago are outmoded. There are more hands to produce; more mouths to consume. There is no surer bulwark against business paralysis than such an expanding population. More than half our people are in the throes of the greatest economic change of the twentieth century — a change for the better, affecting every business in America.

More than half our families live in places of less than 25,000 population — Main Street towns — and on the surrounding farms. Riding in to the 80,000,000 men and women who live or shop on Main Street are new products, new merchandising methods, a new standard of living.

Are you getting your selling message to these families in proportion to their number and buying power? Are you supplementing your coal business, and guaranteeing your future tonnage, by aggressively promoting a good stoker franchise? To maintain your place in the community, you must become an automatic-coal-heat merchant.

Just what do oil and gas salesmen have to sell? In two words, automatic heat. What do we have to sell? More than any oil- or gas-burner manufacturer. First, economy. During an average winter, an Illinois 5- or 6-room home can be heated with 7 tons of stoker-fed coal. The same house under the most favorable climatic conditions will require 1500 gallons of oil. Good stoker coal would mean a heating bill of about $100; oil, $210. Removing clinkers every two days is but a 5-minute task, or 6 hours 15 minutes for the heating season. By using coal, John Q. Public makes $110 in 6 hours 15 minutes. Besides economy, we can sell Cleanliness, Safety, Comfort, Dependability and freedom from worry in case of a power shutdown or similar contingency.

Who Buys Stokers?

An easy question. Everybody buys them. From a survey of 5000 of our users in Chicago I found that white-collar workers totaled 41 percent, professional men 18, and skilled workers 41. In short, the baker, the grocer, the butcher, the dry cleaner, the dairyman, the druggist, the clerk, the accountant, the machinist, the doctor, the lawyer, the Indian chief — all buy stokers. Stokers are sold to your neighbors, the people you play cards with, the people you go to church with, the gang you meet at the lodge. When you get back to your home towns, start talking to all these people about stokers.

How to Sell Stokers

Prospects — How to Find Them

1. The cold-turkey canvass. Much can be said for and against this method of finding prospects. It may be slower than others, but no method is more certain. Here are some pertinent suggestions.

a) Use judgment in selecting your territory. If you are selling a high-priced, residential stoker, don't start in a low-priced, non-home-owner neighborhood.

b) Use intelligence.

c) Don't punch doorbells hit-or-miss. To be successful in this work requires a fine-tooth comb. Don't miss any doorbells.

d) After ringing the doorbell, stay long enough to make sure that nobody is at home before moving on to the next house.

e) After your prospect has answered the door, you can break the ice and give a logical reason for your being there by explaining that you are taking a heating census of the neighborhood. By a short list of worked-out questions you can quickly find the type of heating system, whether the prospect has considered automatic heat, etc. This gives you all the pre-approach information you need for a later call. If the prospect shows interest in automatic heat, some salesmen prefer to swing into their story immediately and try to get permission for a survey or for an appointment to return. Another way is to have junior salesmen or canvassers make this initial approach and merely secure permission for the survey, which is followed up by the regular salesman.

Share-the-Wealth Bond

Give to your satisfied users a printed form in the shape of a regular bond. If they have a lead, let them clip a coupon, write in the prospect's name, and send it to your office. Pay them a $5 or $10 "dividend."

The Good-Neighbor Plan

Once you have made a sale, get the names of your customer's nearest neighbors. Most owners take natural pride in new equipment and have no objection to the salesman's showing their closest neighbors the new installation. The sale of one burner in a block has sometimes been the start of many other sales in the same neighborhood.

Telephone Campaign

This may be used to advantage in some communities. Since most of us are inexperienced in the art of telephone solicitation, an experienced solicitor should be put on the job. The best list of prospects

may usually be secured from coal dealers, so that the solicitor will not waste time calling someone who already has an oil-burner, stoker, or gas-burner.

An inexperienced solicitor kills off many good prospects. Therefore, unless experience has shown that your voice "registers" over the phone, don't yield to the temptation of saving legwork by improper application of this method.

Displays

Because the eye is more retentive than the ear, use attractive displays whenever and wherever you can. This method is usually inexpensive and invariably produces many new leads. If a salesman must spend 90 percent of his time looking for prospects, he can spend only 10 percent in actually securing orders. Displays of many kinds cut down this 90 percent.

a) Outdoor parking lot displays are very effective. The stoker may or may not be under actual fire; if at all possible, though, let customers see the equipment in operation. A hood or bonnet above the retort will carry off the products of combustion. As the curious stop to look, it is the salesman's job to see that they also listen. An easy opening sentence is "Did you ever see our machine in operation?" The answer will show whether the prospect owns a stoker or has been investigating them. Before the prospect leaves, the salesman should have gained permission to make a survey of his home or place of business.

b) The popularity and growth of home shows and exhibits offers an ideal opportunity for a stoker display that may yield hundreds of prospects in a few days. Exhibits of this sort may also be used at state or county fairs, industrial expositions, or wherever large crowds are to gather for an inspection of home, commercial, or industrial equipment.

c) Mounting a stoker on an attractive trailer is a method successfully used by many dealers. Depending on local ordinances, the stoker may or may not be under fire. The portable display will prove a magnet to the curious and a prolific lead-producer for you. It is also possible to bring the trailer to the door of a prospect who refuses to go out on a demonstration. He can scarcely refuse to look.

Chimney Gas Analysis

Some salesmen and dealers have secured many leads through the use of flue gas analyzers and thermometers. These give CO_2 readings and actual draft conditions in the furnace, which may be translated into terms of efficiency. Publicize your offer through the newspaper or by a personal letter or communication. One dealer had a short ad in his local paper offering free chimney gas analysis and explaining simply the advantages of the service. He got hundreds of excellent leads for later sales.

This method enables the salesman to advise a prospect specifically how much fuel may be saved by installation of a stoker. Too often, otherwise, the salesman's estimate of savings is rather a rough guess.

Here are some other suggestions. Cover the city building permits. Solicit furnace men — 75 percent of this business is replacement. Try a personalized letter campaign; especially in July, August, and September a well-worded short and personalized letter to a selected list may produce excellent results. And to repeat—canvass your own neighbors and the people with whom you do business every day.

A Step-by-Step Sales Plan

No such plan can be perfect. On the other hand, no plan at all can lead only to failure. Certain steps are essential in consumating a stoker sale. The following have in many instances produced splendid results:

1. The Survey
2. The Presentation
3. The Demonstration
4. The Price Quotation
5. The Close

The first step is a survey in a man's boiler room. You are not a "salesman" but an "investigator." Having investigated, you are in a position to come back and talk intelligently to the prospect about what he will do in his own particular case.

The second step is a presentation of the facts disclosed by your investigation of his boiler room or basement.

The third step is "proof of the pudding." Remember the Packard slogan, "Ask the man who owns one." Demonstrate the stoker equipment in operation, or the various parts, or give some other kind of visual demonstration that will help verify the story you have presented to the prospect.

The fourth step is the quotation of price. If we have sufficiently established the need in relation to the price, we are ready for the close. This is not necessarily a scene in which the salesman, by sheer power of words, overcomes the prospect and gets an order signed. Rather it is the natural result if the previous steps have been well taken.

By enlarging the plan as follows it becomes even more effective.

1. Make two surveys—a physical survey and a sales survey. The physical survey contains all the necessary measurements of boiler, boiler loads, heat periods, radiation, etc. The sales survey includes finding all the reasons why the prospect should buy the stoker. In other words, what will the stoker do for the prospect?
2. Make two presentations — a written one to leave with the prospect, and a visual one with the aid of your various sales tools.
3. Make two demonstrations — owner demonstration and sales demonstration. In other words, a demonstration in the basement of a satisfied user, and a demonstration in your own showroom where you have a chance to show the prospect the machine in detail, selling him on its mechanical superiority.
4. Make two surveys, two presentations, two demonstrations. But you need only one close to land the order.

Surveys

Permission to Survey

Having located a prospect, get his permission to make a survey of the premises. Remember, we are approaching a man who is usually a total stranger, even though we may have had a personal inquiry from him or though a close personal friend may have sent us to see him.

This call is primarily an ice-breaker to enable us to meet our prospect face to face and get permission to make a survey. These jobs done, pick yourself up by the seat of the trousers and get out.

What about canned sales talks? Well, as a rule a canned talk does sound canned. On the other hand, it's better to have some definite opening remarks than to expect inspiration to hit you suddenly.

Having received permission to make a survey, never leave the man's office till you have a definite date to return for the presentation.

Then request previous fuel data. These *must* be correct, for your estimate will be based on them.

What to Look For in a Domestic Survey

The physical dimensions of the furnace itself are the least important part of the job. The thing to be concerned with is to ascertain sufficient reasons why the prospect should install a stoker. We all know there are certain basic motives—savings, comfort, convenience, cleanliness, the desire to relieve his wife of the burden of firing a furnace, and others. But the fact that a stoker may save $25 on the coal bill, give uniform temperatures, or eliminate ash-removal drudgery may not be sufficient in the prospect's mind to offset his reluctance to part with the money necessary to buy these advantages.

Presentations

There is no rule concerning when to make an oral presentation and when to make a written one.

In smaller communities where the salesman may know the prospect by his first name, the written presentation has no advantages. In other communities it is of unquestioned value.

The advantages of a written presentation include these five:

1. It enables the salesman to tell a consistent, logical story, and stay on the track or get back to it regardless of the prospect's interruptions.
2. It enables him to maintain the prospect's interest.
3. By working up to a logical climax, it aids him in establishing a date for a demonstration in the future.
4. It keeps the salesman, especially the new salesman, from inadvertently divulging the price too early.
5. The written presentation may be left with the customer, to serve as a constant reminder every time he sees it on his desk.

Read the presentation sentence by sentence, with the prospect looking on. Invariably the prospect will reach for the presentation in order to read it himself. Then he will only skim it. If you sit down with him and read the whole document, and particularly if you sit close to the prospect so that he can follow the print, it's bound to seep in. Let him read along with you; otherwise he will get bored during the five or ten minutes it takes to read the presentation aloud.

The presentation does more than tell him the advantages he would gain from installing a stoker. You also wish to present proof in the form of testimonial letters, pictures, and data on the machine itself and to bring forth other sales tools such as slide films, showcases, parts of the machine itself, etc.

All this leads up to one point—to awaken in your prospect enough interest and enthusiasm so that he will go with you for an actual operating demonstration, which is the next logical step.

At this point he will undoubtedly start asking the price. The astute salesman will avoid this subject, knowing that the prospect is not yet sufficiently sold. So, before leaving his office, the next objective is a definite date for a demonstration.

Demonstrations

How to Prepare a Demonstration

The demonstration is your proof, in two parts: What the prospect hears; what the prospect sees.

What the prospect hears, we call owner proof; this part of the demonstration is generally given upstairs. The second part, we like to think of as mechanical proof, in terms of advantages to the prospect. This part of the demonstration is generally given in the basement or else in the dealer's showroom.

If you have a choice, owner proof is the more important. The prospect knows you are being paid; a satisfied owner has nothing to gain or lose by a truthful expression of his feeling toward your products.

The logical place to close a sale is not in the owner's basement but in your own office or showroom. Of course in the sale of a domestic stoker the close may be made in the prospect's own home; but the best "playing" may be done on your own home grounds where there is no telephone interference and where you have any needed additional sales tools at hand.

In chronological order, here are the steps of a demonstration:

1. Plan your demonstration. Do not take the prospect on a demonstration merely because it's the nearest one to his place of business. If he's in the dry-cleaning business, he has no interest in a stoker that has been installed in a greenhouse.
2. Inform the owner in advance. He need not exaggerate or do anything except tell your prospect of his own experience with your equipment. However, it is advisable to let him know that you wish to bring a prospect into his basement, and to ask his permission to do so.
3. Check up on the demonstration points. Up to this time you have a certain amount of time and money invested in your prospect; you don't want to chance losing a sale because for the first time in two or three years this installation might be in poor condition on that day. Find in advance whether the stoker is in proper condition to be shown, whether the boiler room is clean, etc.
4. Having prepared the owner and the scene, prepare the prospect. On the way to the demonstration, review the various sales points that have appealed to him, so that when you point these out on this job that he is going to see, he will recognize and appreciate them. If he is a domestic prospect, take his wife along, particularly when there is some question in her mind about cleanliness. Nothing will convince a housewife as quickly as another housewife who is well satisfied. So if she has a chance to see a clean, modern basement and observe your stoker in operation as well as to talk to the owner's wife, you will have presented her real proof.

5. Go in the front door. Don't try to slide your prospect in the back door and down to the boiler room or by the side entrance. He may think you fear to have him talk to the owner, when that is just what you want him to do. Go in the front way, make the proper introductions, put owner and prospect at ease. Sit down and let the owner have an opportunity to tell your prospect about the cleanliness, the even temperatures, the saving on fuel bills.

Demonstrating the Domestic Stoker

Use Eye-Appealing Names

Hundreds of salesmen can find prospects, get permission to make a survey, make it, and also make the presentation, but when they come to the demonstration they are put off with a stall. Up to that point we have been selling the prospect on what the stoker will do for him. At this stage we must prove that our statements are true and show how we accomplish the results he has been led to expect.

In making a demonstration, therefore, I wish to do three things.

1. I wish to prove to Mr. and Mrs. Prospect that all the claims I have made for my product are true. This I can usually accomplish by "using the user" and having other people who have already received these benefits confirm my story.

2. When I reach the stage where I am ready to discuss the features, I want to make a demonstration that will stick because it means something.

3. During this demonstration I wish to bring out the features so forcibly that, should the prospects decide to "look around a little bit," I will put my competitor in a position where he has to justify any price differential.

Keep in mind that every word we say, every feature we point out, builds a picture in the prospect's mind. It is either a clear picture that translates itself into dollars and cents values, or it means nothing.

It is not practicable to try to tell the average prospect and his wife an involved technical story. Take a tip from nationally advertised products. The public does not like to read engineering treatises.

Now let your prospect walk down the street, if he insists, and into your competitor's place of business. You will usually find that the competitor has a smart salesman who is qualified, like you, to give a good demonstration. He has a retort on his machine, a worm, a worm-housing. He has a hopper, he has control. By the time he has finished demonstrating he has convinced the prospect that he has everything your stoker has and at a lower price.

Translating Nonmechanical Advantages into Dollars and Cents

To meet this competition, you cannot stop with pointing out the features. You must translate them into definite advantages to the prospect—that is, into dollars and cents. For instance, not only point out how the retort is constructed and why; bring out the fact that this construction will save the prospect money during the whole life of the machine. Or, after explaining how the worm is made and why, tell why this particular worm will be trouble-free and save the owner money through low upkeep.

Each of the features on a machine was put there by your manufacturer for some good reason. If you don't know that reason, find out, so that you may stress this feature to your prospect and show how it will save wear on his pocketbook.

Always talk about the pocketbook. That's one thing the prospect understands and appreciates.

Controls as Selling Features

Many salesmen become so enthusiastic over the machine itself that they neglect the controls. After all, the stoker is only a piece of mechanism designed to deliver and efficiently burn a certain number of pounds of coal per hour. The controls are the brains that make this possible. Furthermore, from the psychological viewpoint, the controls are something that the prospect readily understands and can "play with". You can hand him a thermostat and let him set the temperature requirements for his own building. You can show him how the time switch operates and can impress on him the importance of accurate control.

Nearly every advantage he will get from the stoker can be demonstrated by using the controls—for example, even temperature, labor saving, even pressure.

Selling the Company Behind the Product

Never neglect to sell the company that stands behind the product and behind the local dealer or distributor. Of importance to every buyer is the financial responsibility, not only of the distributor, but of the manufacturer. We all like to know who we are dealing with. Don't wait for the prospect to ask you who makes your machine; sell him on the idea that they know their business, are financially responsible, and have a splendid record as a manufacturing concern. The same for the company by whom you are personally employed. At all times, sell The Company Behind The Product.

Callbacks

Though callbacks were not listed in our step-by-step merchandising plan, they are important. They require as thorough preparation as any other step. In fact, they bear about the same relation to the survey, presentation, and demonstration as mortar does to the bricks in a building wall. They help bind the structure together.

You may need them at any stage. Permission to make a survey is not always gained on the first call, and a demonstration may not be concluded in one call.

Figure out carefully in advance what you want to say and the "props" you will use on every callback. Above all, have a logical reason for calling back. Don't irritate your customer by dropping in to remark casually, "Just going by, and dropped in to see if you were ready to sign the order" or "I happen to be in the neighborhood, so I though I'd run in and see if there was anything new."

Rule number 2 is: always have something new to show the customer.

Having with you some new gadget or piece of literature often furnishes the necessary reason for the return call. Showmanship is essential on callbacks; therefore, any gadget you wish to show should be visual. A suggested list of props that may well be used on callbacks (though they are also useful at any stage of the sale) is given below.

1. New literature.
2. Testimonial letters.
3. A candle. Use this (a) to test for leaks in the smoke pipes or breeching; (b) to test draft conditions either at the air inlet in the firing door or at the check damper; and (c) to illustrate the principle of forced underfiring, showing the prospect how the fuel is fed to the fire from below. By inverting the candle you can show him what happens when fuel is placed on the top of the fire. The flame of the candle becomes very smoky, and it requires a good deal more fuel.
4. Your pipe and smoking tobacco — to demonstrate how combustion is achieved with the fuel bed underneath and the flame on top.
5. Frying pans. A small cast-iron frying pan which can be broken with a hammer will illustrate the fallacy of claims for the superiority of cast-iron construction; and a small steel frying pan which cannot be thus broken will show the superiority of pressed steel construction in spite of less weight.
6. A dime and a nickel. Often your competitor tries to justify his machine on the basis that it is bigger and heavier. That this in itself is no argument may be illustrated with a dime and a nickel. The nickel has a larger diameter and greater thickness and more weight, yet it's only half the value of the dime.
7. A dollar bill. Suggest to the prospect, if the price decision is still lacking, that he may be looking at the burner, and advantages that will accrue to him from its installation, with the price too close to his eyes. Hold the dollar bill directly over your eyes. You can't see the stoker or the advantages; all you can see is the price. However, if you lay your dollar bill alongside the stoker, you can see them both with an impartial eye. Then the stoker and its advantages immediately become far larger than the dollar bill.
8. Lamp and glass rod. Emphasize the necessity for proper headroom by placing the glass rod immediately in the flame from a small coal oil lamp. The soot will quickly accumulate on the rod. Show this to the prospect and bring out the point that soot is known as the third best effective insulator in the world, and that $\frac{1}{16}$ inch of soot is said to be equivalent to 1 inch of asbestos. By taking the lamp and turning the wick up and down and closing off the air supply above and below, you illustrate the value of proper air adjustment. A bright flame is needed for good combustion. Lack of air, when you shut off the air supply around the base of the chimney, produces a weak flame and causes smoke. Too much air produces a yellow flame, an indication of incomplete combustion, which results in a waste of fuel. The same is true in his furnace if he is handfiring. Only your stoker can give him the desired results.
9. Simple engineering equations. Point out, for example, that one pound of carbon burning in the presence of CO_2 will release approximately 14,500 Btu. One pound of carbon burning in CO (insufficient air) will release only 4,400. This illustrates that with a deficiency of air as high as two-thirds of the available heat units are wasted. Again your stoker is the answer.

Closing the Sale

As reported by successful salesmen, major things to remember in closing a sale are these (not in chronological order):

1. Be human and service-minded.
2. Use the words "automatic heat" wherever possible.
3. All the way through your story, use the name of your machine instead of the word "stoker."
4. Refer to the contract not as a "contract" but as an "order" or "agreement."
5. Stick strictly to the truth.

6. Make more effective, frequent, and generous use of the tools furnished you by your manufacturer.

7. Be enthusiastic.

8. Always have an order written up in advance and everything entered except price and terms. This saves time, confusion, and mistakes.

9. Be sincere; never use "baloney."

10. Smoke out the prospect's chief objection or objections, so that you may know what to concentrate upon.

11. Keep getting commitments from the prospect. Ask him questions in such a way that he continues to agree with you by saying "yes," "yes," "yes."

12. Take particular pains to determine the prospect's weak points and strike hard at them.

It would be useless to lay down any hard-and-fast rule governing the close. But as stated before, if the previous steps in the sale have been properly conducted, the close is really an anti-climax. If your prospect wants to put you off, it's up to you to give him logical reasons why he should make a purchase now.

If you can't give him logical reasons, he may be correct in his desire to put off the decision. If it's a question of money, help him work out terms he can afford to meet. Use horse-sense and be alert for every possible opening. Above all, never give up. There is no selling thrill like turning "defeat" into "victory."

To sum up the entire sales procedure, I would say:

1. Get the facts.
2. Present the facts in a logical, convincing way.
3. Prove the facts with a demonstration.
4. Quote the price at the proper time.
5. If the facts outweigh the price in the prospect's mind, you have nothing to worry about so far as the order is concerned.
6. Don't forget to get out your order blank and ask for the order early and often.

Competition

Your biggest competitive problem, particularly for the smaller-size burners, is that you are selling a mechanical product to nonmechanically minded prospects, yet the primary difference between any two machines is based on the mechanical superiority of the one over the other. To sell your machine, at say a higher price, your prospect must be made to understand these superior features.

In other words, the entire problem reduces itself to a mathematical equation: better engineering plus better materials equals a superior product, which in turn equals a higher price.

If the layman doesn't understand engineering, materials, and mechanics, he can't appreciate that your product is superior. He can understand only price. How can you expect him to pay a higher price for something he doesn't understand? Therefore, if you are going to sell your machine against competition, you must make it possible for Mr. and Mrs. Layman to understand mechanics. You must translate nuts and bolts into advantages, and advantages into dollars and cents.

Study

The surface has only been scratched in this great stoker market. Automatic heat is just starting to come into its own. The question is: Will you be prepared to take advantage of the business?

For instance, do you know what to study in order to perfect your knowledge of the stoker business? No salesman can learn the art of changing the minds of other men without applying himself consciously to the job. Here are items which you should study religiously:

1. Installation Manual. This should be studied so that you learn thoroughly the application, operation, and types and sizes of burners.

2. Literature. No salesman can tell the story of his stoker as easily, quickly, and clearly as it is embodied in the sales literature provided by the manufacturer. Study every piece of literature that he gives you.

3. Advertising. If your manufacturer advertises on a national basis or in your local publications, draw your prospect's attention to advertisements that suit his own case.

4. Testimonial Letters. A thorough knowledge of the testimonial letters in your sales pack is essential. They offer definite proof of similar cases. Study them. Know the contents so well that you can verify any statement you have made to the prospect.

5. Local Situation. Study your changing local situation. Read the real estate columns and note property that is being sold, new buildings, new homes, etc.

6. Magazine Articles and Trade Journals. Study the trade magazines that have to do with coal and coal burners. Each issue contains excellent ideas and keeps you in step with the industry.

7. Coal Data. Study the local coal situation as to grades available, prices, freight rates, etc. You may obtain pamphlets on coal from the United States Bureau of Mines or state bureaus.

8. Oil and Gas Data. Study the price and the changing situation of competitive fuels, the Btu per thousand cubic feet of gas, etc.

Highly intensified and growing competition in the sales war will force our selling ability to a higher plane. Dramatization by chart, word picture, and demonstration will be one of the answers to several of our problems. The more intelligently we develop the vital elements of dramatization—action, suspense, mystery, and curiosity—the more easily we will be able to sell.

To meet present competition you personally have got to key your sales force to the job and give them the selling tools they need.

But regardless of visual aids, demonstration kits, and other paraphernalia, one characteristic must be an integral part of every sales presentation we make. I mean the power of enthusiasm. It is fundamentally the reason for every success. Enthusiasm is almighty and unfailing. It is the most contagious fever known to man. One second after the fever breaks out in you, it spreads to all those within the range of your voice and personality. It ignores all handicaps, disregards past failures, and refuses to acknowledge any restrictions.

Because of top capacity production, you and I have a job to do — a job that at the moment is probably beyond full realization — a job that will require patience, tolerance, and fortitude — a job that is a challenge to our ingenuity and managerial ability. We can do that job — do it without one iota of fear — if we begin to glow with real enthusiasm. Talk it up! Let yourself go all the way, and note the difference!

XV. SALESMANSHIP IN 1948

H. A. BERGDAHL*

Progress of Salesmanship

Not long ago it was advisable for the customer to beware of salesmen. You remember Barnum's "There's a sucker born every minute." Barnum's autobiography paints a vivid picture of selling practices in many stores around the year 1825:

> Our cottons were sold for wool, our wool and cotton for silk and linen; in fact, nearly everything was different from what it was represented to be. The customers cheated us in their fabrics; we cheated the customers with our goods. Each party expected to be cheated if it was possible. Our eyes and not our ears had to be our masters. We must believe little that we saw and less that we heard.

How salesmanship has changed for the better!

Modern Definition of Salesmanship

What then, you may ask, is a modern definition? If you asked a hundred top-flight sales executives you might get a hundred different answers. But here's one I heard recently that I wish to quote:

> Salesmanship is the power or ability to influence people to buy at a mutual profit that which we have to sell but which they may not have thought of buying until we called their attention to it.

You personally might word your interpretation a bit differently; but for the sake of this discussion, let's base our thinking on that definition.

Components of Modern Salesmanship

Sales Climate

Not many years ago the opinion prevailed that a well-rehearsed, well-memorized canned sales talk would work wonders. Today canned sales talks are considered a bad approach. Instead, we try to have our salesmen develop in themselves what might be called a Sales Climate. No one can determine ahead of time just what problems and questions he will face from customers and prospects. But if the right sales climate is present, the salesman can take whatever steps are necessary as occasions arise — always keeping in mind that the customer is king.

This sales-climate attitude is illustrated by an ad carried by many magazines during the war. It is headed "The Kid in Upper 4." The Kid went off to war. Chances are he had never seen a B-29, a tank, a bazooka. Yet it wasn't many months before this same kid was piloting a $300,000 superfortress over the Pacific, or driving a tank

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into battle, and doing a good job of it. How could he learn so much so soon? Was it because of civilian training in aeronautics or engineering? Probably not. In my opinion, he had the right "climate." He was determined to apply himself to the job at hand and do his best. He was flexible. He knew the meaning of competitive spirit. He knew he *must* succeed or the enemy would come out on top.

Consumer Benefit

There's been a definite trend toward greater use of the Consumer Benefit idea in sales as well as advertising work. At the very moment a sales interview opens, it's important that the salesman gain favorable attention quickly. What's a good way to do this? Well, every normal human being is most likely to be favorably interested in what benefits him. Isn't it logical, then, to start a sales interview by stressing consumer benefits? It's better technique to say, "For comfortable, even heat, you will find our stoker coal is tops" than to say, "Because of special inspections and grading at the mine, our stoker coal is tops and you are assured comfortable, even heat."

Here are a few samples of this idea, from a recent issue of Life:

A Sinclair ad starts: "Use Less Oil — Use Less Gasoline — Get More Power." Nearly all of us would be attracted. Your favorable attention is gained quickly because you want to find out more about using less oil, using less gasoline, getting more power.

"For Extra Shaving Comfort — Plus Economy" (Auto Strop Razor).

"It's Big—It's Beautiful—The Way *You* Like A Car" (Mercury).

"Beat The Heat — Fresh Up" (Seven-Up).

"How To Make 4 Fresh Cooked Meals From Half A Ham" (American Meat Institute).

"Effective — Refreshing" (Squibb's Dental Cream).

"For Fast, Easy Car Polishing" (DuPont Polish).

"Whose Bread I Eat"

Another important factor in salesmanship is expressed in these words: "Whose bread I eat, his praise I sing." Simple; yet how often this basic fundamental of selling is abused. Take the case of one of our salesmen in Texas. He got a nice order which was promptly forwarded to the Chicago factory. Though the order plainly gave all boxing instructions and other needed information, when the finished products reached Texas the customer was furious because, for the second time, they were improperly boxed. The salesman said, "I don't know what's the matter with that bunch in Chicago. I marked the order just as you told me. They seem to ignore the instructions."

Maybe that salesman feels he is building his own prestige by proving that the error was not his. But the opposite is true. The company, the product, the salesman are all held in lower regard by the customer because of the salesman's charges of inefficiency or indifference by the home office.

The point is: good salesmanship requires that you sing the praises of *all* connected with your industry. True, you will have some irritated, unreasonable customers; but *never* do good salesmen belittle or condemn their company or their industry to their customers.

"What the Eye Perceives"

Once there was a general notion that salesmanship required only a gift of gab. To this day, too many salesmen talk too much. They make too little use of the prospect's other senses — especially sight. Here's a saying with real meat in it for salesmen:

What the eye perceives
The heart believes.

The dictionary tells me that "perceives" means "understands." If the eye understands, the heart will believe. Medical men say that the optic nerve leading from the eye to the brain is twenty times as large as the nerve which leads from the ear to the brain. Fortified with this knowledge, the man who is working for a quick order makes it his business to so maneuver the interview that at the earliest possible moment he puts in the prospect's hands a sample of what he is selling (or a miniature of it), or a chart, graph, diagram, blueprint— anything, in fact, that will employ the prospect's sense of sight.

When anyone tries to tell you that talking is all there is to selling, remind him that three quarters of all knowledge we gather from cradle to grave comes through our eyes, and only one tenth through our ears.

Samples in your business? Your selling efforts will be more productive if you always remember that What the eye perceives, the heart believes.

I have touched on but a few factors of salesmanship — Sales Climate, Consumer Benefits, "Whose Bread I Eat," and "What The Eye Perceives." I don't suppose anyone ever learns all there is to know about this most interesting subject. But I do hope I have given you some food for thought and some suggestions that will aid you in your sales efforts.

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